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Influence of Trickle and Surface Irrigation on Return Flow Quality

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A field plot study was conducted to determine the effects of controlled surface irrigation and trickle irrigation on the quality and quantity of irrigation return flow. The surface-irrigated plots showed an increase in salt concentration with depth to the clay-sand interface. Below the clay-sand interface at 80-100 cm, a sharp decrease in salt concentration was observed. It appeared that a larger change in soil salinity was produced by altering irrigation frequency than by changing irrigation efficiency. Irrigating when 50 percent of the soil water had been depleted was the irrigation frequency most conducive to salt retention by the soils. Trickle irrigation was effective in controlling the volume of return flow, while maintaining relatively low salinity levels in the soil around the trickle emitters. Accumulated salts were readily moved away from trickle lines by preplant irrigation or rainfall. The mean salt concentration of the irrigation return flow, as estimated from deep soil solution samples, agreed well with the average salt concentration of the groundwater to a depth of 11 meters. Below 11 meters the salt content of the groundwater decreased.

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INFLUENCE OF TRICKLE AND SURFACE IRRIGATION ON RETURN FLOW QUALITY

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ABSTRACT

A field study was conducted to determine the effects of controlled surface irrigation and trickle irrigation on the quality and quantity of irrigation return flow. Trickle irrigation resulted in cotton yields (3-year averages) which were 8.2 percent higher than those from the surface-irrigated plots, and with trickle irrigation 24 percent less water was used than with surface irrigation.

Data on soil salt accumulation in the surface-irrigated plots showed an increase in salt concentration with depth to the clay-sand interface. Below the clay-sand interface at 80-100 cm, a sharp decrease in salt concentration was observed. It appeared that a larger change in soil salinity was produced by altering irrigation frequency than by changing irrigation efficiency. Irrigating when 50 percent of the soil water had been depleted was the irrigation frequency most conducive to salt retention by the soils.

It appeared that trickle irrigation was quite effective in controlling the volume of return flow, while maintaining relatively low salinity levels in the soil around the trickle emitters. Accumulated salts were readily moved away from trickle lines by heavy preplant irrigations or intense rains.

The mean salt concentration of the irrigation return flow, as estimated from deep soil solution samples, agreed well with the average salt concentration of the groundwater at a depth of 11 m. Below 11 m the salt content of the groundwater decreased. The quality of irrigation return flow entering the Del Rio Drain agreed with the average concentration of the groundwater at depths of 6 to 26 m, but not with the quality of the groundwater measured at a single depth.

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SECTION 1

INTRODUCTION

Maintaining the quality of river water is a major problem in the Western United States. In New Mexico, the salt concentration in the Rio Grande increases progressively going downstream from Santa Fe, in the north, to El Paso on the New Mexico-Texas border in the south. The greatest increases in salt concentration occur in reaches where irrigated agriculture is practiced (the rate of increase is more than twice that of non-irrigated reaches) and is related to irrigation return flow.

Irrigation return flow originates when water in excess of evapotranspiration is applied to the soil-plant system. The excess water is applied intentionally to leach soluble salts from the plant root zone and insure perennial agriculture. That portion of the excess water flowing back to the river is called irrigation return flow.

This report presents information from field studies which were conducted to determine the effects of irrigation management on the quality of irrigation return flow. By reducing the amount of water used for irrigation and improving irrigation efficiency, the amount of water percolating through the soil and entering the groundwater table or drains is reduced. Thus proper management of irrigation water application is important for controlling the quality of irrigation return flow.

The general objective of this project was to determine the effects of improved irrigation methods, i.e., controlled surface irrigation and trickle irrigation, on the quality and quantity of irrigation return flow.

The project objectives were:

1) to determine the effects of the depth and frequency of surface irrigation on water and solute transport within soil profiles.
2) to determine the effect of water management on composition and quality of percolating water from field plots under trickle irrigation and to determine the feasibility of minimizing percolation losses by trickle irrigation.
3) to compare the results of this study with the quality of water in the Del Rio Drain, and relate this to the quality of irrigation water applied.

The research was divided into three parts. Field plot experiments were conducted at the New Mexico State University (NMSU) Plant Science Research Center near Las Cruces, New Mexico. For each plot, extensive determinations of cotton yield, soil salinity, quality of percolating water, and crop water use were made. In addition, measurements of the salt build-up around trickle lines were made.

For part two, water sampling stations were established at two locations along the Del Rio Drain. The quantity and quality of the water passing these two stations were measured once a week throughout the experiment.

For part three of the project, a battery of two-inch wells was installed to monitor the quality of the water in the subsoil in the plot area.

SECTION II
SUMMARY

The salt concentration of the water in the Rio Grande in New Mexico increases progressively as the river goes downstream from Santa Fe in Northern New Mexico to El Paso, Texas. The greatest increases in salt concentration occur in reaches where irrigation is practiced due to the return to the river of lower quality drainage water (irrigation return flow).

This report presents information from a 3-1/2 year field study which was conducted to determine the effects of irrigation management on the quality of drainage return flow. The general objective of the project was to determine the effects of controlled surface irrigation and trickle irrigation on the quality and quantity of irrigation return flow. The study consisted of three parts. For part one, field plot experiments were conducted at the NMSU Plant Science Research Center near Las Cruces, New Mexico. Some of the field plots were irrigated by surface irrigation and others by trickle irrigation. Extensive determinations were made of cotton yield, soil salinity, quality of percolating water, and consumptive use of water for each plot. For part two, water sampling stations were established at two locations along the Del Rio Drain near the farm. The quantity and quality of the water passing these two stations were measured once a week for the duration of the experiment. For part three of the project, a battery of two-inch wells was installed to monitor the quality of the water in the subsoil of the plot area.

Crop water use and deep percolation losses were estimated using three different procedures. Because of the extreme heterogeneity of the soil at the experimental site, both horizontally and with depth, percolation losses could not be accurately calculated by multiplying hydraulic gradient by the unsaturated hydraulic conductivity below the root zone. The abrupt layering of the subsoil also resulted in unreliable water use data as obtained from neutron probe readings. Climatological methods appeared most feasible to estimate deep percolation losses. Based on the latter method, average deep percolation losses of 19.3 cm in 1973 and 21.9 cm in 1974 were estimated for the combined surface irrigation treatments. With a five-month growing season, this amounted to an average downward flux of about 1.4 mm/day.

During each project year, the amounts of water used on the trickle plots were smaller than those used on the surface irrigated plots including the 100 percent efficiency surface treatment. In 1973, the average amount of water applied to the 100 percent efficiency treatment was 67.1 cm versus 54.3 cm applied to the trickle plots, or about 20 percent less with trickle irrigation. In 1974, these amounts were 77.5 cm versus 56.0 cm or a water savings of 28 percent with trickle irrigation.

Irrigation treatments had no significant effect on cotton yield at the 5 percent confidence level. However, for the surface irrigated plots, the 50 percent depletion treatment yielded more cotton than did the 25 percent and 75 percent depletion treatments at the 90 percent and 100 percent levels of efficiency. Yields tended to decrease with increasing percent efficiency with the exception of the 50 percent depletion treatments. For 1972-1974, the mean yield from all surface irrigated plots was 1090 kg lint cotton per ha, versus 1180 kg/ha for all trickle irrigated plots. Thus the trickle plots produced on the average 8.2 percent more lint cotton than the surface irrigated plots and used 24 percent less irrigation water.

The salt distribution in all plots was measured after each irrigation season by taking soil samples at 20-cm depth intervals to 160-cm. Saturation extracts were prepared and the electrical conductivities (and during one year the composition) of the extracts determined. The large spatial variability of soil salinity made it difficult to detect any statistically significant differences due to surface irrigation treatments. Thus, soil salinity was independent of efficiency treatments and depletion treatments applied. However, depletion had five times the effect on salinity that efficiency had, indicating that for the study area, a greater change in salinity would be produced by altering irrigation frequency than by altering irrigation efficiency.

From 1972-1974, there was a slight increase in the salt content of the surface irrigated plots, from an average of 0.173 g/100g of soil in the fall of 1972 to 0.189 g/100g in the fall of 1974. This increase in salt content was most pronounced for the 50 percent depletion treatment. It was negative for the 25 percent depletion treatment.

The salinity data indicated a large increase in soluble salts with depth to about 100 cm, and then a decrease. The high salt concentration at the 60-100-cm depth as compared with the salt concentration in the underlying sand was mainly due to higher concentrations of Ca, Mg and SO_4. Salt concentrations at 60-100 cm were double those at 120-140 cm.

It proved to be extremely difficult to extract soil solution samples through suction cups placed in the sandy subsoil below the root zone. As a result, these data are somewhat incomplete, and the coefficients of variation are high. The average electrical conductivity of the soil solution samples collected over the three years was 7.89 mmhos/cm. This value was found to be on the average 4.2 times higher than the mean conductivity of the saturation extracts of soil samples taken at the same depth in the profile. The only significant treatment effect on electrical conductivity of the soil solution samples was depletion. The salt concentration of the percolation water from the 75 percent depletion plots was significantly lower (at the 5 percent level of probability), than the salt concentration of the water from the 25 and 50 percent depletion plots. This agreed with the measurements on total salt in the profile as determined from saturation extracts.

Treatment had no significant effect on the total salts accumulated in the trickle-irrigated plots, but did affect the salt distribution around the trickle lines. The plots in the drier trickle treatment accumulated salts closer to the soil surface than did those in the 0.2 bar treatment. Salt distribution around trickle lines was also measured with salinity sensors. The sensors performed satisfactorily and provided a rapid measurement of the response of salt distribution to irrigation or rainfall. The data showed that preplant irrigations through trickle lines were very effective in moving salts away from the lines, thus providing a seed bed of low salt concentration.

Excellent data were obtained on the quality of the groundwater at five levels below the soil surface. The water quality of the monitoring wells changed, with depth, from a mean electrical conductivity of 1.63 mmhos/cm at 5.8 m to 1.09 mmhos/cm at 22.9 m. Assuming a bulk density of 1.6 for the sandy subsoil, the saturated water content in this zone was calculated to be 38.9 percent by volume. The volumetric water content in the unsaturated sandy subsoil averaged about 8 percent. On this basis, the electrical conductivity of the water in the unsaturated zone should be 4.86 times the electrical conductivity of the shallow groundwater. The observed ratio of these electrical conductivities was 7.89/1.63 = 4.84, which is in excellent agreement.

Flow measurements at both sampling stations on the Del Rio Drain showed a sharp increase in flow in early March, followed by a second relative peak in flow rate in July-August during all three years of the study. The data revealed that the increase in drain flow between the two sites was 0.11 m^3/sec or +18 percent, during at least 50 percent of the time. No estimates were available on the actual area drained by this section of the Del Rio Drain.

The mean salt content of the drain water was found to increase from 908 ppm at site A to 953 ppm at site B 4.5 km downstream, an increase of 10 ppm/km of drain. A frequency distribution of the salt concentration showed that 50 percent of the time the salinity could be expected to increase at a rate of 0.86 percent per km of drain. The quality of water entering the drain between the two measuring sites was calculated from the increase in concentration and flow between the sites, and agreed fairly well with the mean quality of the water sampled from the test wells and irrigation well. The quality of the water from any one test well, however, did not adequately represent the quality of the water entering the drain. Thus, in order to estimate the quality of the water entering a drain, the saturated zone has to be sampled at several depths.

SECTION III
CONCLUSIONS

1. As much as 32 percent of the water applied to the surface irrigated plots was lost by percolation to the subsoil. Drainage losses ranged from 32 percent of the total water applied on the treatment designed for 80 percent water use efficiency to 21 percent of the water applied on the treatment designed for 100 percent water use efficiency. Assuming a 5-month irrigation season, this resulted in average downward fluxes of 1.5 and 1.0 mm/day, respectively, for these treatments.
2. Total water use, as estimated with the irrigation scheduling system, agreed closely with total amount of irrigation water applied to the trickle plots, irrigated on the basis of tensiometer data.
3. For the stratified-heterogenous soils of the Mesilla Valley, it appeared more reliable to estimate deep percolation losses with the water balance method, based on estimates of consumptive use, than from soil hydraulic conductivity and water content data.
4. Determining irrigation efficiency from frequent water content measurements with the neutron probe was unreliable. This was due to rapid drainage losses immediately following heavy irrigations, to uncertainty in the neutron meter calibration curve near saturation for the clay-loam soil in the upper 70 cm of the profile, and to systematic errors in water content measurements near the clay-sand interface at around 70 cm below most of the field plots.
5. Surface irrigation treatments had no significant effect on cotton yields at the 5 percent level of probability. However, yields tended to decrease with increasing efficiency, and the 50 percent depletion treatment yielded more than the 25 and 75 percent depletion treatments.
6. The trickle-irrigated plots used 30 percent less water than the surface-irrigated plots in 1973 and 28 percent less water in 1974. Averaged over all years and treatments, the trickle plots yielded 8.2 percent more lint cotton than did the surface-irrigated plots. Thus, it appeared feasible to minimize water losses with trickle irrigation while maintaining, at least for three years, yields as good or better than those obtained with surface irrigation.

7. Surface and trickle irrigation treatments had no significant effect on the economically important cotton quality parameters.
8. Soil salinity of the surface-irrigated plots was not affected significantly (at the 5 percent level of probability) by irrigation treatments. Treatment effects were largely obscured due to the large spatial variability of soil salinity over the experimental area. However, irrigating when 50 percent of soil water had depleted caused a consistent trend toward increasing total salt in the soil profile.
9. With preplant irrigation through the trickle system and rainfall in the summer, a region of relatively low salt content was maintained around trickle lines. The drier trickle irrigation treatment accumulated more salt close to the soil surface than did the wet irrigation treatment.
10. The quality of water in the upper part of the saturated zone appeared to be in equilibrium with the quality of the water percolating from the unsaturated zone above it.
11. The quality of the groundwater varied with depth from 5 to 23 m. Below 11 m, the salt content of the groundwater started to decrease. It was 35 percent less at 23 m than at 5 m. Due to this variation of salt content with depth in the saturated zone, the quality of the return flow entering the Del Rio Drain could not be estimated from the quality of groundwater measured at one depth, only.
12. The quality of the return flow entering the Del Rio Drain between two sampling stations was estimated from differences in the concentrations of salt and differences in the flow rates measured at these two stations. The calculated salt concentration of the return flow was in agreement with the average concentration of the groundwater between 5 and 23 m. The increase in drain flow between the two stations was found to be 0.11 m^3/sec, or +18 percent at least 50 percent of the time. The increase in salt load was 0.86 percent per km length of drain 50 percent of the time.

SECTION IV
RECOMMENDATIONS

1. The results of this study indicate that with proper irrigation management salts may be retained in the soil profile. Because the long-term effects of salt retention in layered field soils on yield have not been adequately studied, it is recommended that such studies be initiated to evaluate the long-term effects of improved water management practices on yields.
2. Field scale testing of trickle irrigation for high value crops such as chile, lettuce and seed alfalfa is recommended. These tests should include water use measurements and monitoring of salt levels in the soil around the trickle lines.
3. Prediction of irrigation needs on the basis of climatological data and of crops and soils information is a practical method for reducing water requirements in the Mesilla Valley thus reducing the volume of return flow. However, a large-scale application of this method should be accompanied by a system of sampling representative fields for salt build-up in the profile.
4. Due to the large variation in physical and chemical properties of the soils, spatially and with depth, and because of the large amount of salt present in the soils of the study area, changes in soil salinity or in return flow quality are not easily detected in short-term experiments. It is therefore recommended that detailed field plot studies conducted under controlled conditions to determine the long-term effects of irrigation management on soil salinity and quality of return flow be continued.
5. Increased effort is needed to determine actual evapotranspiration data for various crops and soils in the Mesilla Valley.
6. A network of shallow test wells should be established in the Mesilla Valley to monitor the quality of shallow groundwater. At each location the groundwater quality should be monitored at several depths.
7. The data from this study indicate considerable accumulation of salts at or near the soils interface of clay over sand. Any accumulation of salt in soil profiles will affect the quality of water percolating to the water table and thus affect quality of return flow. In order to understand the development of salinity profiles in stratified soils, detailed studies of the simultaneous movement of water and salts are necessary. The

presence of a sharp clay/sand interface has a great effect on soil-water movement and was suspected to have an effect on the precipitation and dissolution of salts.

8. Future studies should include development and testing of models to predict the effect of irrigation management on return flow quality. Such models should include soil-water chemistry in the unsaturated zone as well as water chemistry and water movement in the saturated zone. A combination of intelligent data collection and model development will provide a more rapid means of estimating effects of irrigation management on quality of return flow than will any singular approach.

SECTION V
MATERIALS AND METHODS

FIELD FACILITIES

The farm, prior to purchase by the University in 1970, had been under irrigation for a long time. The crops grown in the study area were mainly cotton, alfalfa, and chile. The farm was served by the Elephant Butte Irrigation District, and the quality of the Rio Grande water at Las Cruces Dam was representative of the water used for irrigation in the past.

Before installation of the plots, the field area was leveled then flood irrigated with approximately 20 cm of water. Soil samples were taken during construction of the field plots in order to determine salt distribution with depth prior to the start of irrigation treatments. Additional soil samples were taken outside of each plot during the fall of 1974.

The project was located at the Plant Science Research Center of New Mexico State University, about eight miles south and west of Las Cruces, New Mexico.

The soil at the site was heterogeneous which is characteristic of alluvial soils in the Mesilla Valley. The soil profile consisted of about 30-cm silty clay loam over 20 to 30 cm of clay, over a variable amount of silty loam. The latter changed rather abruptly into a medium sand. The depth to the sand on the two acre site varied from 60 to 120 cm below the soil surface. Root penetration into the medium to fine sandy subsoil appeared to be almost negligible.

In Figure 1, the field plot layout at the experimental site is presented. The experimental design consisted of thirty 7.3 x 7.3 meter plots and six 6.1 x 18.3 meter plots. The 7.3 x 7.3 meter plots were irrigated by surface irrigation and the 6.1 x 18.3 meter plots were irrigated by trickle or drip irrigation. Each surface-irrigated plot had its own alfalfa valve, which was connected through a 10-cm I.D. underground pipeline to the 30-cm I.D. irrigation well just outside the plot area.

A water flow meter was installed in the main line from the well in order to meter the correct amount of water to each surface-irrigated plot. These plots were separated from the surrounding soil by polyethylene plastic to a depth of 75 cm below the soil surface. The plastic around the plots served to prevent horizontal water movement out of the plot area, which may otherwise have taken

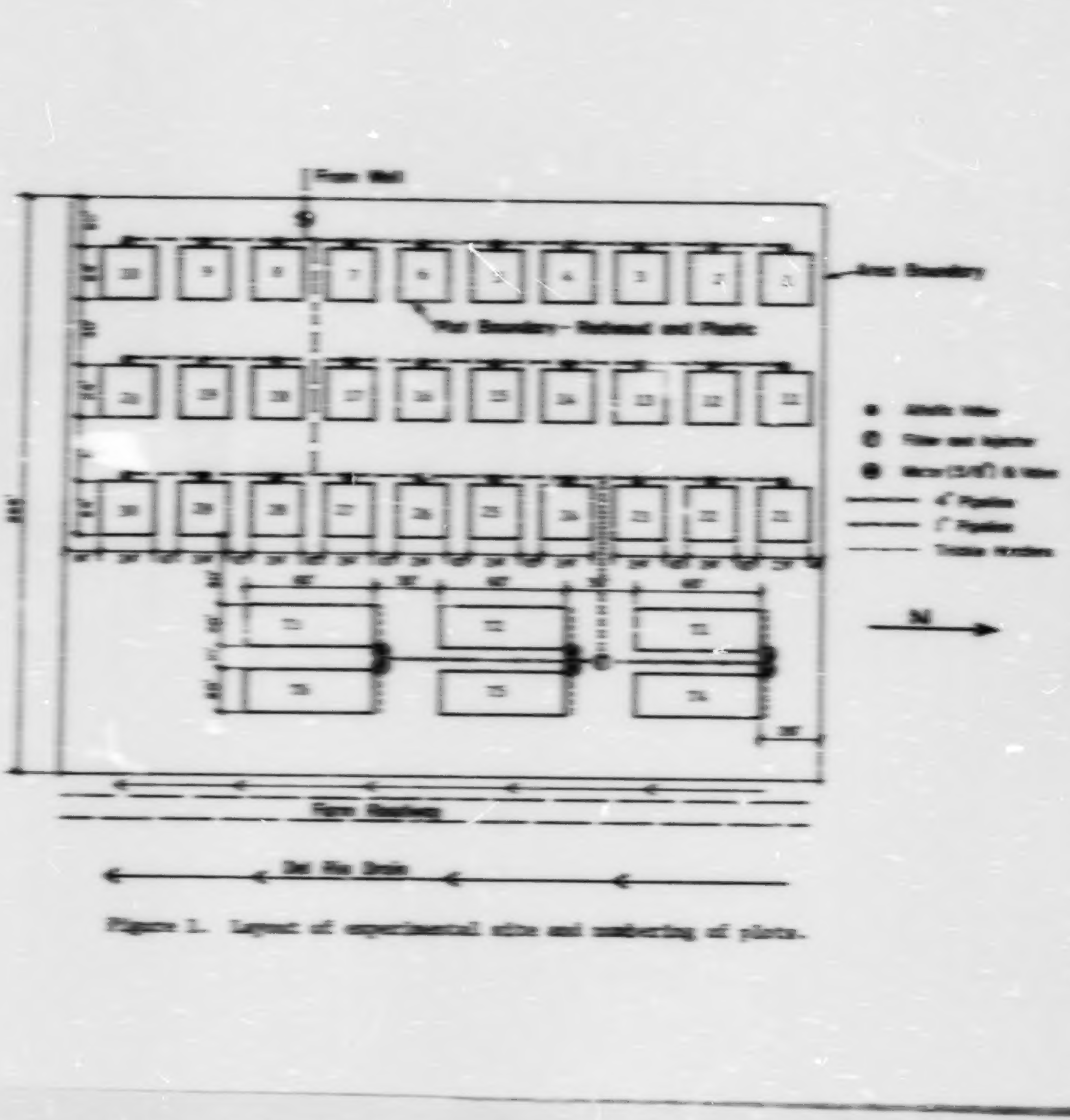
From Well
Area Boundary
Plot Boundary—Redwood and Plastic
10
9
8
7
6
5
4
3
2
1
Alfalfa Valve
Filter and Injector
4" Pipeline
1" Pipeline
N
Farm Roadway

Figure 1. Layout of experimental site and numbering of plots.

place due to the low permeability of the 40-60-cm layer. Wooden boards extending 20 cm above the soil surface and 10-cm below, covered with polyethylene plastic, prevented surface runoff from the plots.

The trickle system consisted of 1-cm I.D. trickle lines at 1-m row spacing and having Drip-Eze emitters (Controlled Water Emission Systems, El Cajon, California) every 45 cm of trickle line. Initially the pressure in the trickle lines was maintained at 1 atm. During the last two years, flow control valves were used to control the amount of water going to each plot. An emission rate of 3.6 liters per hour (equivalent to 8 mm per cm^2 per hour) per emitter was used. For each trickle-irrigated plot, a separate positive displacement water meter was used to measure the amount of water delivered. The water meters were calibrated annually.

The irrigation well installation consisted of a 30-cm hole, 26-m deep, gravel packed and screened with a 20-cm I.D. Wesco Keystone slotted screen extending from 17 to 26 m. Water table depth was 3.7 m. The water lubricated vertical turbine pump (bowls set at 17 m) delivered 19 l/sec (300 gpm) at a dynamic head of 27 m. The pump was driven at approximately 3600 rpm with a 10 hp (480v., 3-phase, 60Hz) electric motor.

A battery of five observation wells was installed to monitor quality changes in the underlying aquifer and to monitor the water quality versus depth relationship within the shallow aquifer. The wells extended to depths of 5.8, 8.2, 11.0, 15.5 and 22.9 meters. The casings were 3.2-cm I.D. (1-1/4 inch) schedule 200 PVC pipe, and each casing had a 60-cm section of slotted plastic well screen at the bottom. The five wells were valved to a common manifold and individually sampled with a pitcher pump. After 1-1/2 years, the pitcher pump was replaced by a suction system with nylon tubing leading into separate collection bottles. During each sampling, sufficient volumes of water were removed from each well to assure a representative sample from the specified sample depth.

Two sampling stations were established along the Del Rio Drain. The Del Rio Drain runs approximately parallel to the Rio Grande for a distance of about 32 km and drains a large portion of the Mesilla Valley. It is one of the eight major drains in the valley having continuous flow throughout the year. The drain borders the experimental site to the east. One station, station B, was constructed adjacent to the plot area and the second station, station A, was constructed 4.5 km upstream. Water samples were taken at the two stations at weekly intervals starting in December 1971.

The flow rates at the sampling stations were also monitored. Staff gauges were installed at culvert inlets near each sampling station. Foot bridges from which current meter readings could be made were installed 10 meters upstream from the culverts. Current meter readings were taken weekly, and the quantity of flow computed for each station. Stevens water stage recorders were installed at each site to obtain a continuous record of stage and thus of flow rate. A stage discharge curve for each site was constructed. Because of vandalism, the water stage recorders were functional during only part of the project. Flow meter readings, however, were made at weekly intervals throughout the project.

FIELD MEASUREMENTS

Water content was measured with neutron probes manufactured by Troxler Electronic Laboratories, Raleigh, North Carolina. The equipment consisted of a Model 1255, 100 millicurie americium-beryllium probe and a Model 2651 digital scaler. A calibration curve was constructed from neutron meter readings and the water contents determined for gravimetric soil samples taken at the same time and in the same general soil volume. Each time neutron readings were made, the calibration curve was modified according to the neutron counts obtained on a set of three standards provided by the manufacturer. It was necessary to frequently calibrate all probes and meters against factory standards over the duration of the experiment because the use of different probes and rate meters as well as instrument repairs shifted the calibration. By this method, the water contents obtained before and after repairs, or the water contents obtained with different probes were comparable.

Neutron readings were made near the center of each plot through aluminum access tubes, 3.1 cm O.D. and 150 or 180 cm long. When not in use, each tube was closed by a rubber stopper to prevent its filling with water during irrigations.

Tensiometers were installed at two depths in each plot to determine the hydraulic gradient below the root zone of the cotton crop. It had been observed, on adjacent cotton fields, that roots would not penetrate the sands underlying the clay loam. Since the sand was reached at a depth of 60 cm in the first row of plots but was often as deep as 120 cm in the third row of plots, it was decided to place the tensiometers at increasing depths from the first row to the third row. Hence, in plots 1-10, triplicate tensiometers were installed at 120 cm and at 150 cm below the soil surface. In plots 11-20 the tensiometers were installed at depths of 135 and 165 cm, and in plots 21-30 and in the trickle plots, the tensiometers were installed at depths of 150 and 180 cm. This insured that the gradient was measured below the root zone.

All tensiometers were connected by buried nylon tubing to mercury manometers placed in louvered instrument shelters outside the plots. A great deal of effort was needed to keep the tensiometers, a total of 198, in operating condition. The nylon tubing, where exposed to sunlight, became brittle and had to be replaced each year. During the irrigation season the tensiometers were read at regular time intervals. The data were punched on cards and the hydraulic gradients calculated and averaged by computer for each treatment over various time periods.

Suction cup samplers were installed to sample the quality of the water percolating from the root zone to the groundwater table. The samplers consisted of a variable length of 2.2-cm O.D. PVC tubing (schedule 80) attached to a tensiometer cup 5.8-cm long. Samplers were installed near the center of each plot at a depth halfway in between that of the tensiometers. Thus, in row 1 (plots 1-10) the suction cups were placed at 135 cm; in row 2 (plots 11-20) at 150 cm; and in row 3 (plots 21-30) and in the trickle plots at 165 cm. A hole slightly smaller than the outside diameter of the sampler was driven to a depth of about 10 cm above the final depth of the sampler. The sampler was than pushed in to its proper depth as specified above. All suction cups were connected by buried vacuum lines to collection bottles outside of each plot. A constant suction was maintained on the sample collection bottles by means of an underground vacuum system connected to a central vacuum pump located in the instrument van. Initially, a vacuum of about 0.6 atm was used to obtain soil solution samples However, frequently no sample was obtained probably due to excessive evaporation. When a vacuum of about 0.15 atm was applied, better results were obtained. Since a vacuum sometimes had to be applied for several days in order to extract a sample, there may have been some concentrating effect on the solution samples in the collection flasks. Mineral oil was initially added to the collection flasks to prevent evaporation from the samples, but was found to interfere with the chemical analyses, and its use was discontinued.

Several times during the experiment, soil samples were taken within the plots at 20-cm depth intervals to 160 cm. These samples were taken at two locations within each surface-irrigated plot and composited for analysis by depth. Trickle plot soil samples were taken from four locations within each plot. Two locations were selected below a trickle line and two locations were selected in between two trickle lines, the two "below" samples for each depth combined for analysis and the two "between" samples for each depth combined for analysis. Saturation extracts were made from all samples and the electrical conductivities (EC_e) determined. Samples collected in the spring of 1973 were subjected to a complete chemical analysis for water soluble anions and cations, pH and electrical conductivity.

Soil samples were taken during the following periods:

1. Fall 1972 - inside plots; EC_e only
2. Spring 1973 - inside plots; complete analysis
3. Fall 1973 - inside plots; EC_e only
4. Fall 1974 - inside and adjacent to plots; EC_e only

Salinity sensors from Soil Moisture Equipment Corp., Santa Barbara, California, Model No. 5000-A, were used to measure salt distribution around trickle lines. The salinity sensors were installed in 2.5-cm diameter holes which had been punched to the desired depth. Contact was maintained between the ceramic portion of the salinity sensor and the soil by means of a compression spring. To insure that there was no water and salt movement to the sensor via the installation hole, approximately 10 cm of the hole was backfilled with soil, capped with polyethylene film, and the remainder of the hole backfilled with original soil. The factory calibrated and temperature compensated salinity sensors were used to obtain salinity readings in conjunction with a Model 5500 salinity bridge.

The first group of salinity sensors was installed in June 1972. Fifteen sensors were installed in a symmetrical grid pattern around a trickle line in plot T2 ("wet" treatment), and fifteen sensors were similarly installed around a trickle line in plot T5 ("dry" treatment). For each of the two plots, the sensors were installed at depths of 10, 25, and 40 cm, and at distances of 0, 15, 30 and 45 cm from the trickle line on both sides. The grid coordinates (distance from line, depth) in cm were: (0,10), (0,25), (0,40), (15,10), (15, 25), (15,40), (30,10), (30,25) and (45,25). On August 1, 1973, additional salinity sensors were installed in each of the two plots to complete the grid to a depth of 40 cm, to include a new depth of 5 cm and to encompass an adjacent trickle line.

A weather station was set up west of the experimental site to measure incoming solar radiation, wind velocity, air temperature, relative humidity, rainfall, pan evaporation, and maximum and minimum temperature.

Incoming solar radiation was measured with a pyrheliometer (Epply Laboratory Inc., Newport, Rhode Island) which had a sensitivity of 8.3 millivolts per cal cm^{-2} min^{-1}. During the first year of operation, the output from the pyrheliometer was recorded on a data acquisition system (Non-Linear Systems, Inc., Del Mar, California) and the millivolt readings punched on cards and integrated by computer to obtain the total daily incoming solar radiation. During the second year, a strip chart recorder was used to record the data which were then integrated by computer. Near the end of the project, a modified Thurtell integrator was used to record and accumulate incoming solar radiation.

Wind velocity was measured at 2 m above the soil surface with an anemometer (Belfort Instrument Co., Baltimore, Maryland, Cat. No. 5-349A, United States Weather Bureau Spec. No. 453.6104) which was read daily in the morning.

Air temperature at 2 m was measured initially with a thermocouple and recorded with the data acquisition system. During the last year of the project, air temperature was measured with a hygrothermograph (Weather Measure Corporation, Sacramento, California, Model No. H311). Daily maximum and minimum air temperatures were measured with maximum and minimum thermometers.

Relative humidity was initially measured with a Brady Aray humidity sensor (Thunder Scientific, Albuquerque, N.M.), and the output recorded on the data acquisition system. The humidity sensor had performed satisfactorily under laboratory conditions but failed in the field. During the last year of the study, relative humidity was measured with the hygrothermograph which, after initial calibration in the laboratory, was regularly checked in the field with a portable electric fan psychrometer. Rainfall was measured with a standard 8-inch rain gauge, and evaporation was measured with a U.S. Weather Bureau Class A pan (Weather Measure Corporation, Sacramento, California, Model No. W311). All transducers were housed in a standard United States Weather Bureau Shelter.

PHYSICAL PROPERTIES OF THE SOIL

A particle size analysis was run on soil samples taken from three different sites near plot 4 using the pipette method of Kilmer and Alexander (1949). The results, which are presented in Table 1, indicate extensive layering of the soil at the experimental site.

Table 1. MEAN PARTICLE SIZE DISTRIBUTION OF SOIL NEAR PLOT 4

Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture
10-20	21.8	43.3	34.9	Clay
20-35	18.2	41.9	39.9	Silty clay
40-50	2.1	50.7	47.2	Silty clay
55-65	4.9	52.6	42.5	Silty clay
70-80	56.4	6.4	37.2	Sandy loam
85-95	94.7	1.0	4.3	Sand
115-125	93.0	2.1	4.9	Sand
145-155	94.6	1.6	3.8	Sand

Note: All values are the mean of three determinations.

Samples were taken for bulk density determination with an Uhland core sampler (Utah Research Foundation, Logan, Utah) and with a hydraulic soil auger (Giddings Manufacturing Company, Fort Collins, Colorado). Three locations around plot 4, and also locations near plots 3, 28, and 29 were sampled. The results are presented in Table 2.

Disturbed soil samples were saturated with .01N $CaCl_2$, placed in rubber rings on a pressure plate membrane (Soil Moisture Equipment Corp., Santa Barbara, California), and a pressure of 15 atmospheres applied. After equilibration, the samples were removed and their water contents determined. The results are presented in Table 3 for the surface-irrigated plots and in Table 4 for the trickle-irrigated plots. These data again clearly demonstrate the vari-

Table 2. BULK DENSITY VALUES FOR THE SOIL AT THE EXPERIMENTAL SITE

Plot 3, East
(means of three values, Uhland sampler)

Depth(cm)	0-15	15-25	25-35	35-45	45-55	55-65
BD (g/cm³)	1.26	1.30	1.38	1.47	1.34	1.33

Plot 1
(means of three values, Uhland sampler, sand at 60-cm)

Depth(cm)	0-20	20-40	40-60	60-75	75-100	100-120	120-140	140-160
BD (g/cm³)	1.42	1.38	1.29	1.54	1.52	1.49	1.61	1.61

Plot 28, West
(10-cm cores, Giddings auger, sand at 90-cm)

Depth(cm)	0-10	10-20	20-30	30-40	40-50	50-60	60-65	76-81	81-91	91-101
BD (g/cm³)	—	1.39	1.41	1.42	1.41	1.33	1.32	1.25	1.37	1.49

Plot 28, South
(10-cm cores, Giddings auger)

Depth(cm)	0-10	10-20	20-30	30-40	40-50	50-60	60-70
BD (g/cm³)	1.36	1.49	1.39	1.39	1.30	—	1.30

Plot 28, East
(5-cm cores, Giddings auger, sand at 120-cm)

Depth(cm)	0-15	15-25	25-35	35-45	45-55	55-65	65-75	75-85	85-95	95-105	105-115
BD (g/cm³)	1.45	1.45	1.49	1.34	1.37	1.32	1.31	1.26	1.38	1.26	1.35

Table 3. WATER CONTENTS, IN % DRY WEIGHT AT 15 BARS PRESSURE FOR 27 SURFACE-IRRIGATED PLOTS

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
1	31.6	32.8	35.9	28.0	8.5	2.1	1.5	1.2
2	22.8	23.1	30.1	13.5	2.5	1.8	1.6	1.5
3	23.1	22.4	28.2	24.8	2.9	1.7	1.4	1.3
5	22.5	23.2	26.2	12.1	3.7	1.5	1.0	1.9
6	26.8	27.8	33.1	21.6	3.4	1.5	1.8	1.3
7	25.7	23.6	26.9	21.6	3.6	1.8	1.6	2.5
8	28.5	29.2	33.6	37.1	5.6	4.3	1.7	1.3
9	28.1	31.4	36.7	34.9	12.4	5.3	3.1	1.8
10	31.3	31.8	34.7	23.7	5.2	1.8	1.9	1.5
11	28.7	25.2	29.8	29.5	9.3	1.3	1.1	1.6
12	28.3	24.2	30.0	31.6	2.6	1.2	0.9	1.6
13	31.8	32.7	38.0	21.6	4.5	1.7	1.4	1.3
14	25.2	30.3	32.7	18.6	3.3	0.9	1.6	1.0
15	29.2	30.4	29.9	17.3	2.9	1.1	0.7	0.8
16	26.1	23.4	22.8	12.7	4.6	1.9	1.3	2.0
17	31.2	31.0	30.6	20.2	4.4	1.9	1.9	1.7
18	28.3	27.1	28.0	28.9	6.5	1.3	1.1	1.2
20	27.5	25.2	26.6	24.4	7.0	2.0	1.5	1.7
21	29.3	29.2	25.7	7.4	14.1	25.7	12.3	3.6
22	30.7	31.1	15.2	8.3	7.1	15.3	16.3	2.2
23	33.6	32.8	26.3	6.9	10.1	16.2	9.7	3.1
24	27.8	26.3	27.7	18.3	14.3	23.4	8.3	3.0
25	22.7	27.0	12.6	15.7	9.3	29.8	24.5	3.8
26	30.2	26.1	33.0	35.8	35.8	10.1	22.0	17.7
27	28.9	29.9	31.1	28.8	10.1	20.5	9.1	10.4
29	25.0	27.4	31.0	33.7	15.1	6.8	6.7	8.6
30	31.7	32.4	33.6	37.1	10.5	2.9	3.3	1.6
Mean plots 1-30	27.9	28.0	28.8	22.4	8.1	7.2	5.2	3.0
St. Dev. plots 1-30	3.2	3.5	5.5	8.8	6.8	9.1	6.6	3.7
Mean plots 1-20	27.5	27.4	30.7	22.9	5.2	2.0	1.5	1.5
St. Dev. plots 1-20	3.1	3.8	4.2	6.5	2.7	1.1	0.5	0.4

ability of the subsoil at the experimental site. The first two rows of plots are much more similar than the third row of plots, as shown by comparing the standard deviation for all surface-irrigated plots with the standard deviation for the first two rows only (plots 1-20). The standard deviation was considerably decreased by excluding the data for the third row of plots.

The amount of plant available water in stratified soils is difficult to estimate. At the experimental site, a variable thickness of clay loam is underlain by sand. A commonly accepted concept in soil physics is that a coarse-textured subsoil causes overlying fine soils to "hold" more water after irrigation, than would be held by uniform fine-textured soils.

Plant available water was initially assumed to be the amount of water held by the soil at water potentials between 1/3 atm and 15 atm. The data in Table 3 show that the amount of water held by the first 20 surface-irrigated plots at 15 atm was about 27.2 percent by weight for the upper 80 cm of soil. This is equivalent to 38.1 percent by volume (assuming an average bulk density of 1.4). With a bulk density of 1.4, the porosity is 48 percent. Thus after a heavy irrigation, the water content would be no more than 48 percent by volume. The "available water", then, would at most be 48 - 38 = 10 percent. For an 80-cm profile, this amounts to 8.0 cm water. The available water may also be estimated from the difference in the water content of the profile one or two days after irrigation and the water content at the end of the growing season, when the plants have used up most of the readily available water. Using the latter procedure, estimates ranged from 12 to 15-cm available water for an 80-cm soil profile, considerably above the values obtained from the 15 atm water content and the saturated water content.

For the purpose of the irrigation scheduling program, the available water was estimated to be 5 cm per 30 cm of soil. This amounted to 13.3-cm for an 80-cm profile. The depth of the profile was assumed to be the same as the depth to the sand. Since this depth was different for each plot, the mean rooting depths for each treatment were calculated separately. The mean estimated root depths and the estimated available water are given in Table 5 for each treatment.

Hydraulic conductivity as a function of water content was determined following the procedure described by Nielsen et al. (1964) and van Bavel et al. (1968).

Table 4. WATER CONTENTS, IN % DRY WEIGHT, AT 15 BARS PRESSURE FOR THE SIX TRICKLE-IRRIGATED PLOTS

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
1 row	28.6	29.3	28.5	7.5	10.1	15.5	5.3	10.4
1 center	28.7	28.5	25.1	15.8	21.7	12.0	4.7	6.9
2 row	23.3	20.8	22.5	6.6	9.4	11.6	4.3	5.6
2 center	21.5	21.9	12.0	5.9	11.3	17.9	4.0	6.0
3 row	21.7	22.9	15.0	4.4	4.7	9.2	6.2	3.2
3 center	35.2	36.6	30.5	8.1	16.7	21.0	8.8	6.0
4 row	35.1	36.0	25.2	11.4	5.0	8.6	3.8	1.7
4 center	26.5	23.6	27.7	11.5	10.6	17.8	6.8	9.0
5 row	31.7	21.7	31.8	18.0	15.5	16.6	8.9	2.2
5 center	30.6	30.7	24.9	15.2	16.3	15.9	8.3	10.0
6 row	30.1	25.8	18.5	7.1	9.8	12.0	10.0	5.3
6 center	21.0	23.7	15.9	6.4	10.6	17.4	10.1	8.7
Mean	27.7	26.8	22.9	9.8	11.8	14.6	6.8	6.3
St. Dev.	5.2	5.5	6.5	4.5	5.0	3.9	2.4	2.9

Table 5. ESTIMATED ROOT DEPTHS AND AVAILABLE WATER FOR SURFACE IRRIGATION TREATMENTS

Treatment No.	Root depth (cm)	Available water (cm)
1	72	12.0
2	68	13.3
3	70	11.7
4	71	11.8
5	72	12.0
6	69	11.5
7	68	11.3
8	75	12.5
9	69	11.5

The soil profile was thoroughly wetted by applying 45 cm of water. Following infiltration, the soil surface was covered with black polyethylene plastic. Cumulative water loss from the soil by drainage was measured with a neutron probe at time intervals varying between one half day and several days. Simultaneously, the hydraulic gradients in the subsoil were obtained from tensiometer readings. From estimated drainage fluxes and hydraulic gradients, values of hydraulic conductivity were calculated.

Graphs depicting the change in hydraulic conductivity with water content are presented in Fig. 2 for four different depths in plot 4. The figure shows that the hydraulic conductivity in the sandy subsoil (below 75 cm) changes very rapidly with water content. Therefore, in order to estimate deep percolation losses, accurate measurements of the water content were required in addition to knowledge of the hydraulic conductivity-water content relationships for every plot.

An indication of the variability in water content of the subsoil in the field can be obtained from the data in Table 3, where the water contents at 15 atm pressure are presented. In Table 6, the water contents are presented for the depth in each plot where the hydraulic gradient was measured. The water contents were obtained from neutron probe data taken during the period February through December 1974. During this period the water content of the sand at 125 to 150 cm remained nearly constant. However, the plot-to-plot variation was relatively large, particularly in the third row of plots. For the first two rows, the mean was about 12 percent by volume and the standard deviation about the mean was 3.5 percent by volume. It is obvious from Fig. 2 that the hydraulic conductivity changed orders of magnitude over the range of water contents presented in Table 6. This made it impossible to obtain representative hydraulic conductivity values for each plot from measurements taken in only one or two plots.

LABORATORY PROCEDURES

All water samples and soil solution samples taken in the field were brought to the laboratory for analysis. The procedures for analysis were basically those described in "Methods for Chemical Analysis of Water and Wastes" (Environmental Protection Agency, 1971).

Electrical conductivity was determined using a Barnstead conductivity bridge.

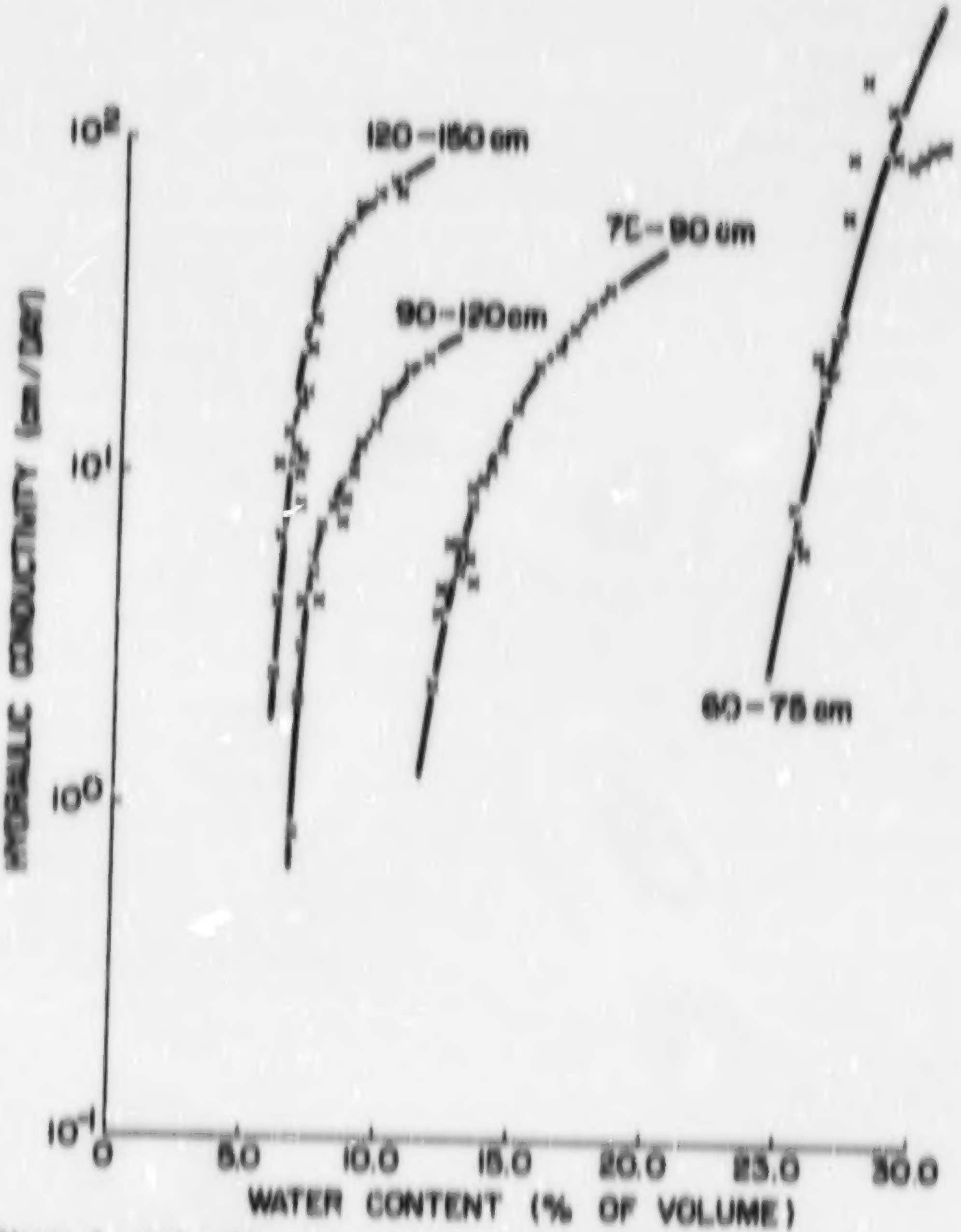

Figure 2. Hydraulic conductivity as a function of water content at several depths for the soils in plot 4.

Table 6. AVERAGE WATER CONTENTS OF THE SUBSOIL (SURFACE-IRRIGATED PLOTS) MEASURED WITH A NEUTRON PROBE DURING 1974

Plot no.	Water content (volume percent) at:		
	125 cm	150 cm	180 cm
1	8.58	10.40	-
2	9.29	11.84	-
3	8.59	9.19	-
5	11.16	11.09	-
6	15.63	11.26	-
7	13.62	12.86	-
8	15.21	15.98	-
9	14.10	13.92	-
10	17.94	16.64	-
11	7.50	8.34	-
12	9.30	25.99	-
13	18.57	16.26	-
14	11.31	12.47	-
15	9.37	11.50	-
16	10.20	9.93	-
17	10.28	10.16	-
18	12.58	11.95	-
20	11.95	15.49	-
21	24.60	13.29	11.81
22	24.97	19.71	27.82
23	40.43	21.35	21.85
24	19.75	10.92	11.43
25	50.78	34.22	40.86
26	49.81	23.08	8.71
27	8.92	9.30	8.42
29	16.50	10.06	14.46
30	10.95	8.75	9.96
Mean plots 1-30	17.11	14.17	17.26
St. dev. plots 1-30	11.83	5.99	10.99
Mean plots 1-20	11.95	12.85	-
St. dev. plots 1-20	3.27	3.92	-

The pH was determined with a digital pH meter. An atomic absorption-flame emission spectrophotometer was utilized in the analysis of the cations, sodium and potassium concentrations determined by flame emission and calcium and magnesium determined by atomic absorption. Procedures described in "Analytical Methods for Atomic Absorption Spectrophotometry" (Perkin-Elmer, 1971) were used for these determinations. Sulfate concentrations were determined by the nitrchromeazo titrimetric method developed by Rasnick and Nakayama (1973). Carbonate and bicarbonate concentrations were determined by titration with 0.01 N sulfuric acid in the presence of phenolphthalein and methyl orange (U.S. Salinity Laboratory, 1954). Chloride analysis was completed on a Buchler-Cotlove chloridometer (Cotlove et al. 1958). Nitrate analyses were done spectrophotometrically (Lambert and Dubois, 1971).

EXPERIMENTAL DESIGN OF FIELD PLOT STUDY

The main treatment effects on the surface irrigated plots were frequency of irrigation and water application efficiency where water application efficiency is defined as the percentage of the water applied that is actually stored in the root zone for use by the crops (Willardson, 1972). Frequency was determined on the basis of the amount of "available" water in the soil profile, where "available" water was defined as discussed above. Treatments included the scheduling of an irrigation when 25, 50 or 75 percent of the available water was depleted from the root zone at a predetermined efficiency. Three field water application efficiencies were selected: 50, 75 and 100 percent for the first year of study, and 80, 90 and 100 percent efficiency for the last two years of study. At 50 percent efficiency, half of the applied water was lost by deep percolation, while ideally none was lost at 100 percent efficiency. The main treatment effects consisted of combinations of three frequencies of irrigation with three field water application efficiencies, resulting in a total of nine treatments. Each treatment was block randomized with three replications per treatment, resulting in 27 surface-irrigated plots. Of the six trickle irrigated plots, three were irrigated to maintain a soil water tension of less than 0.2 bars at a depth of 15 cm. In the other three plots the soil water tension at a depth of 15 cm was kept at 0.6 bars or less. Table 7 summarizes the plots in each treatment and the treatments as applied during 1973 and 1974.

Table 7. SUMMARY OF IRRIGATION TREATMENTS AND PLOTS ASSIGNED TO EACH TREATMENT

Treatment number	Depletion (%)	Efficiency (%)	Plot numbers
	Surface-irrigated plots		
1	25	80	2,14,29
2	50	80	5,20,25
3	75	80	6,16,21
4	25	90	10,18,24
5	50	90	1,15,30
6	75	90	3,11,23
7	25	100	9,12,26
8	50	100	8,17,27
9	75	100	7,13,22
	Trickle-irrigated plots		
02	0.2 atm	--	3,4,5
06	0.6 atm	--	1,2,6

CROP MANAGEMENT

After preirrigation with 15 to 25 cm of water, the surface and trickle-irrigated plots were planted with cotton, Acala 1517-70. All plots were planted without bedding on a 1-m row spacing using a small hand planter. Planting was during the last two weeks of April or the first week of May. Fertilizer was applied in a shallow trench next to each cotton row during the first week of June. Amounts applied were 134 kg N/ha and 67 kg P_2O_5/ha.

Yields were estimated from the cotton obtained by hand picking the center five rows on each surface-irrigated plot and the center four rows on the trickle-irrigated plots. Total row length harvested was 30.5 m (100 ft) on the surface-irrigated plots and 61 m (200 ft) on the trickle-irrigated plots. All plots were harvested twice. The first harvest was generally during the first two weeks of October, and the second harvest was about four weeks later. After the second harvest, the cotton stalks were manually removed from the soil. Cultivation of the plots was limited to rototilling the surface-irrigated plots after preirrigation and before planting. Although this procedure is different from what the farmers in the area use, the small size of the plots made it impossible to use standard farming practices. Following preirrigations, the soil in the trickle plots was in excellent condition, so no rototilling or tillage was necessary.

After planting in 1973 and 1974, a sandcap was applied over the rows to aid in germination and to prevent severe crusting of the surface soil. This procedure was used for the surface-irrigated plots only as there was never any surface crust formation on the trickle-irrigated plots or problems with germination.

IRRIGATION MANAGEMENT

The scheduling of irrigation water for the various treatments was based upon climatological data and on soil and crop data from the experimental plots. During the 1972 season, irrigation intervals and amounts were determined by pan evaporation data, corrected with a stage of growth dependent crop coefficient and adjusted for rainfall. The coefficients based on stage of growth had been developed for use on the Salt River Project in Arizona, and were modified slightly because of the cooler nights in Las Cruces. The shape of the modified relationship is shown in Fig. 3.

During the 1973 and 1974 seasons, irrigation intervals and amounts were based on the Irrigation Scheduling Service (ISS) of the Bureau of Reclamation. This program, originally developed by Jensen (Jensen et al. 1972), schedules irrigations from meterological data combined with soil, crops and experimental information.

A weather station was established at the Plant Science Research Center adjacent to the study area, and the following measurements were made: incoming solar radiation, temperature, humidity, daily wind run at 2 m, pan evaporation and rainfall (see under climatic data). The Bureau of Reclamation used these same data for scheduling irrigations on farms in the vicinity of the Plant Science Research Center.

The Jensen-Haise equation was used for computing evapotranspiration. It has the form:

$$ETP = C_t (T - T_x) R_s \qquad (1)$$

where T is the mean daily air temperature in °F, R_s is the daily solar incoming radiation in inches evaporation equivalent, and C_t and T_x are coefficients.

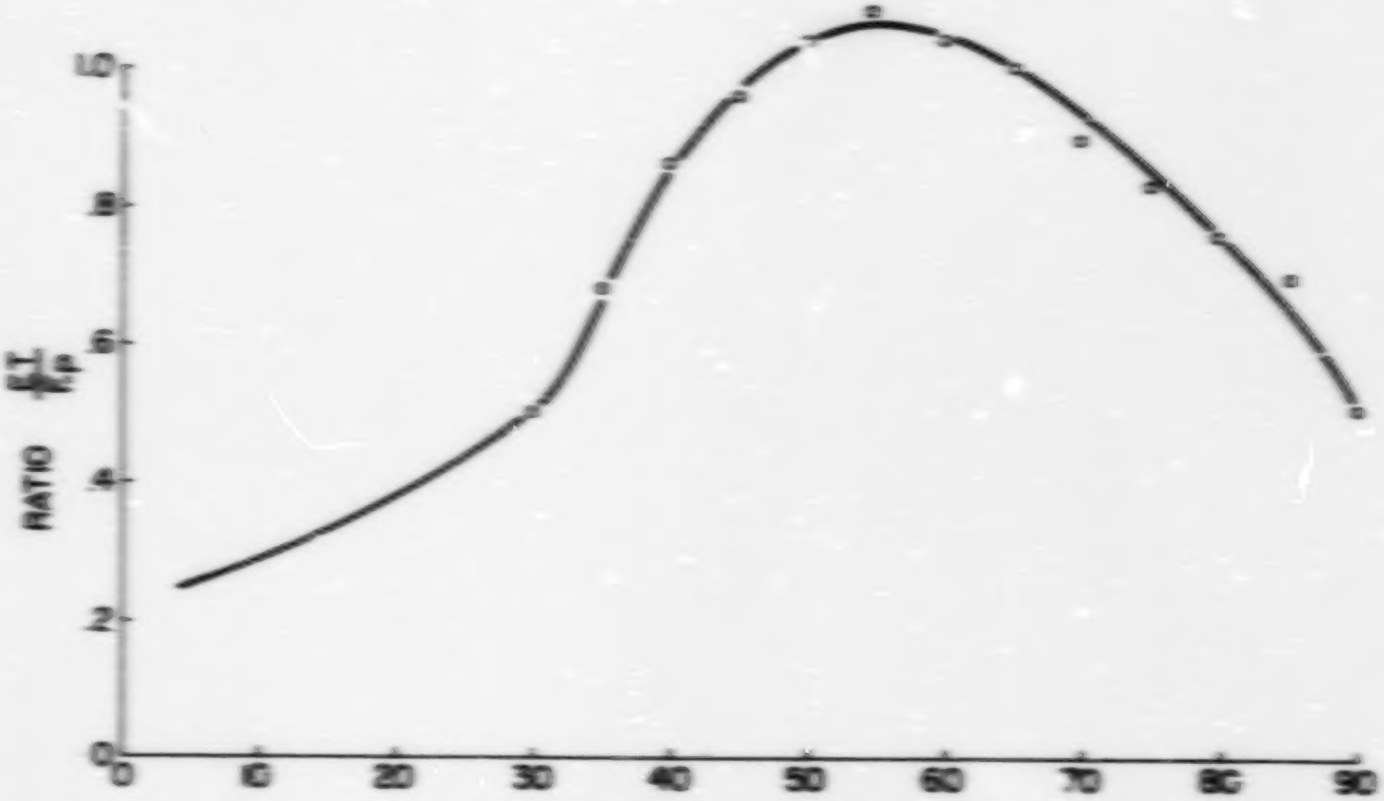

Figure 1. Ratio of evapotranspiration to pan evaporation for cotton as a function of percent of growing season elapsed.

The values for C_t and T_x used in the El Paso - Las Cruces area are .0066 and -24, respectively. Therefore, equation (1) becomes:

$$ETP = 0.0066\ (T + 24)\ R_s \qquad (2)$$

To get the actual daily evapotranspiration (ET) for cotton, ETP is multiplied by a crop coefficient, K_c, and a soil moisture coefficient, K_s, as follows:

$$ET = K_c \times K_s \times ETP \qquad (3)$$

The value of the crop coefficient K_c varies with the stage of growth of each crop. The K_c curve used for cotton in the local area is presented in Fig. 4. The soil moisture coefficient reflects the availability of soil moisture at the time of computation. The adjustment is small when soil moisture is high and becomes greater as the available soil moisture decreases according to:

$$K_s = \frac{\ln\ (AM + 1)}{\ln\ (101)} \qquad (4)$$

where AM is the percent of available moisture in the root zone. The maximum available moisture in the root zone and the maximum rooting depths for each surface treatment used in the program are listed in Table 5.

The increase in evaporation from the wet soil surface immediately following an irrigation or rainfall was accounted for in the following manner:

1. Adjusted ET = Computed ET + (Percent x Adjustment)
2. Adjustment = $(0.9 - K_c\ K_s) \times ETP$
3. No adjustment the day of rain or after 4 days following rain, and no adjustment if $K_c\ K_s \geq 0.9$.
4. First day after rain: 80 percent x adjustment
   Second day after rain: 50 percent x adjustment
   Third day after rain: 30 percent x adjustment
5. Adjustment following an irrigation is the same; also no ET computed for the day of the irrigation.

The effective cover date at which the crop began to require water at the peak rate was taken to be August 7 in 1973, and August 13 in 1974. A 60-cm root zone was assumed at planting. Increases in the depth of the root zone were made in 15-cm increments, until the maximum depth was reached at 80 percent of the time from planting to effective cover. Effective precipitation was assumed to be the total precipitation from rains greater than 2.5-mm.

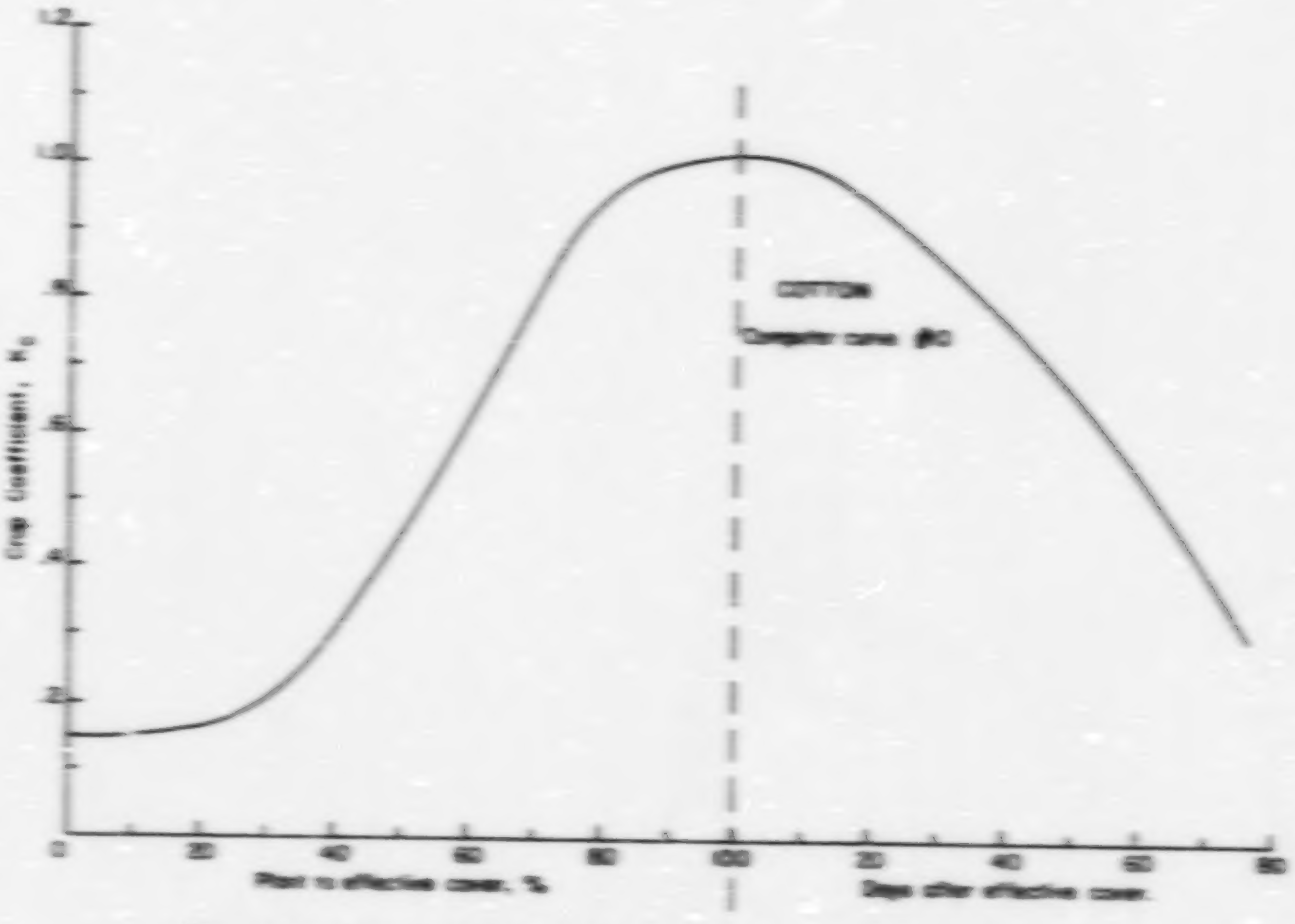

Figure 4. Crop coefficient (K_c) used in the Jensen-Haise equation to estimate evapotranspiration.

SECTION VI

RESULTS AND DISCUSSION

The results of this study will be discussed according to the objectives stated in the introduction. First, the effects of surface irrigation treatments on water and solute movement within the soil profile will be discussed. Included will be the data obtained from the five deep wells, and also the effect of irrigation treatments on cotton yield. The second objective, i.e., to determine the effects of water management on composition and quality of percolating water in plots under trickle irrigation, will be discussed next.

In the third section, the quality of the water in the Del Rio Drain will be discussed and compared with the quality of the water percolating from the field plots and with the quality of the water from the deep wells, the irrigation well, and from the Rio Grande during the irrigation season.

SURFACE IRRIGATION

Percolation Losses

From Soil Hydraulic Properties - Percolation losses during the experiment were to be determined from knowledge of the hydraulic conductivity and the hydraulic gradient as measured in each plot. During each of the three crop years, the hydraulic gradients were measured with triplicate tensiometers placed at two depths well below the root zone in each plot.

The tensiometers were connected to mercury manometers outside of each plot. From the manometer readings, soil-water tensions were calculated for each depth below the soil surface. The hydraulic gradients were computed directly from soil-water tensions.

An example of the variation in soil-water tension with time is presented in Fig. 5 for Plot 22 for the 1973 crop year.

The data for Plot 22 show a fairly constant soil-water tension at both depths until the end of August. After September 1, though there was no irrigation, the cotton was apparently still using water causing a gradual increase in soil-water tension at 150 and 180 cm.

Figure 6 shows the hydraulic gradient averaged for plots 7, 13, and 22 (Treatment 9) at various time intervals during the 1973 crop year. There is considerable variation in the gradient. During July and August, the gradient was

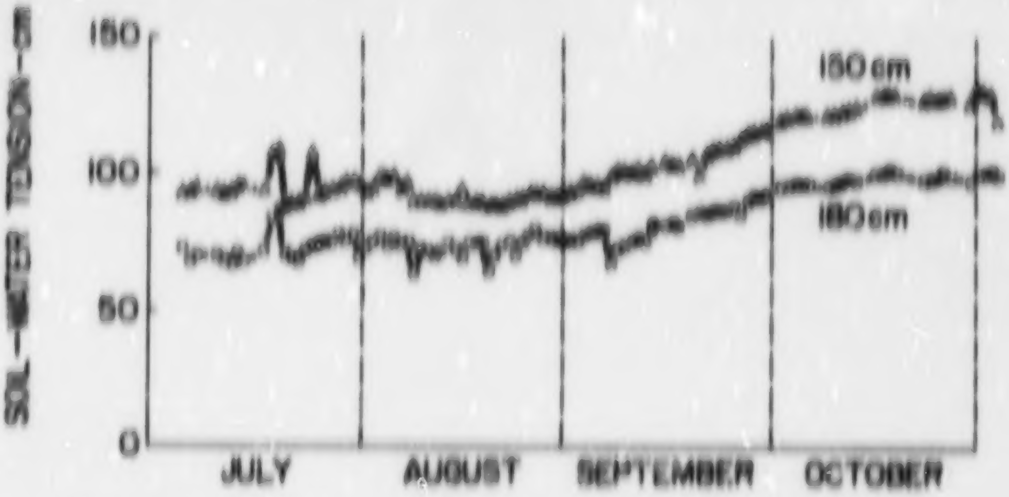

Figure 5. Variation of soil-water tensions (cm of H_2O) at the 150- and 180-cm depths with time (plot 22).

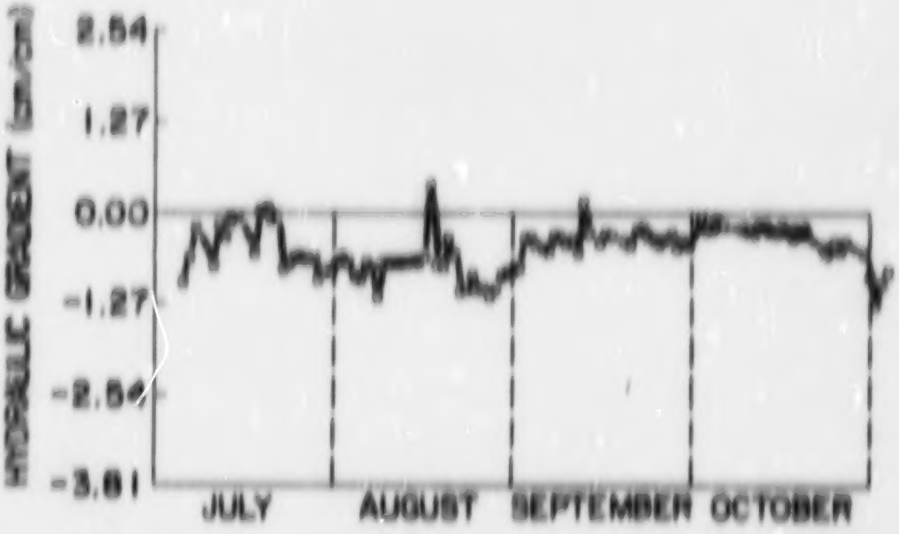

Figure 6. Variation of the mean hydraulic gradient between the 150- and 180-cm depths for Treatment 9.

approximately unity with a slow increase in September due to drying of the soil above the tensiometers. A gradient of unity means downward movement of soil-water at a rate equal to the hydraulic conductivity of the soil at the prevalent water content.

No significant differences were found between the average hydraulic gradients of the treatments. Therefore, the monthly gradients of the treatments were averaged for all plots. The results for 1973 and 1974 were:

	1973	1974
June	-0.86	-0.61
July	-1.10	-0.78
August	-0.84	-0.90
September	-0.58	-0.76

At all times and for all plots the hydraulic gradients were near unity, as expected, and directed downward, indicating some downward movement of water.

The hydraulic conductivity of the sandy subsoil at the experimental site varied widely with water content (Figure 2). Small changes in water content result in large changes in hydraulic conductivity. As a result, the water content of the soil layer where the hydraulic gradient is measured needs to be known very precisely. The precision of the neutron probe was usually within ± 1 percent by volume. However, a one percent variation in water content may lead to errors of 200 to 300 percent in estimates of hydraulic conductivity (fig. 2).

A further complication is that the hydraulic properties of the subsoil at the experimental site vary widely from plot to plot, as evidenced from the data in Tables 1, 3 and 6.

For example, during the 1974 irrigation season, the mean water content of the first two rows of plots (plots 1-20) at 125-150 cm was 12.5 percent by volume with a standard deviation of about 4 percent by volume (Table 6). Although during the year the water content at tensiometer depths in each plot remained fairly constant, the large plot-to-plot variations in water content caused the spatial variability of the hydraulic conductivity over the experimental site to be great. For these reasons it became impossible to accurately estimate deep percolation losses from each plot, using conductivity relationships obtained for a number of test plots.

In conclusion, estimates could not be made of the deep percolation losses from each treatment using the concept of conductivity times gradient. Although the hydraulic gradients were close to unity during a large part of the irrigation season, the uncertainties in the measured water contents and in the hydraulic conductivities corresponding to these water contents precluded calculation of deep percolation losses for treatments with the necessary precision.

From climatological data - The first year, a Class A evaporation pan was used in estimating crop water use (ET), while during the second and third year, the Irrigation Scheduling Service (ISS) of the Bureau of Reclamation was used (See Irrigation Management, page 28) to estimate ET.

By comparing actual amounts of water applied, irrigation + rainfall, with estimated crop water use (ET), deep percolation losses could be determined.

In order to present the irrigation and rainfall data in a uniform manner, the irrigation season is divided into three segments: preirrigation, seeding to stand establishment, and stand establishment to harvest taken to be October 31.

The irrigation and rainfall data for these time segments are presented in Tables 8, 9 and 10 for 1972, 1973 and 1974, respectively. These irrigation and rainfall data show considerable variation from year to year in the quantity of water applied during seedling emergence. This variation was mainly caused by the presence or absence of rainfall. The variation in water applied from stand establishment to harvest is due largely to the change from evaporation pan to ISS in estimating crop water use and the change in treatments from 1972 to 1973.

In establishing a stand in 1974, it was found that frequent irrigation was necessary to keep the soil from forming a crust during a period of unusually high winds and high air temperatures. In the other years small rains greatly reduced the quantity of irrigation water required to obtain seedling emergence. Thus, to provide reasonable comparisons of irrigation efficiencies from year to year, columns titled "Total" in Tables 8, 9 and 10 were used to construct Table 11.

In Table 11, the total amounts of irrigation and rainfall (from stand establishment to harvest) are presented together with the computed evapotranspiration from pan data (1972) and from the ISS program (1973 and 1974).

Table 8. IRRIGATION AND RAINFALL DATA FOR SURFACE PLOTS AT THE INDICATED TIME INTERVALS (1972)

Treatment No.	Preirrigation (cm)	Seeding to stand estab. Irrigation (cm)	Seeding to stand estab. Rain (cm)	Stand estab. to harvest Irrigation (cm)	Stand estab. to harvest Rain[a] (cm)	Total[b] (cm)	
1	20.5	0.0	4.1	72.0	22.6	106.6	
2	20.7	0.0	4.1	72.6	22.6	108.5	105.9
3	20.5	0.0	4.1	68.3	22.6	102.6	
4	20.4	0.0	4.1	51.6	22.6	85.8	
5	20.5	0.0	4.1	56.1	22.6	88.7	85.7
6	20.6	0.0	4.1	48.5	22.6	82.6	
7	20.[illegible]	0.0	4.1	42.7	22.6	76.6	
8	20.6	0.0	4.1	42.1	22.6	77.2	75.7
9	20.8	0.0	4.1	39.1	22.6	73.2	

[a] To October 31, only rains of intensity greater than 0.25 cm considered.

[b] Total = total water applied (irrigation plus rainfall) from stand establishment to harvest + final soil-water depletion (plant available water, Table 5, page 22).

Table 9. IRRIGATION AND RAINFALL DATA FOR SURFACE PLOTS AT THE INDICATED TIME INTERVALS (1973)

Treatment No.	Preirrigation[a] (cm)	Seeding to stand estab. Irrigation (cm)	Seeding to stand estab. Rain[b] (cm)	Stand estab. to harvest Irrigation (cm)	Stand estab. to harvest Rain[b] (cm)	Total[c] (cm)	
1	11.9	7.5	1.8	53.7	18.4	84.1	
2	10.3	9.6	1.8	54.0	18.4	85.7	81.7
3	11.1	7.0	1.8	45.1	18.4	75.3	
4	11.8	8.0	1.8	44.0	18.4	74.2	
5	11.9	8.1	1.8	48.3	18.4	78.7	73.6
6	14.1	8.2	1.8	37.9	18.4	67.8	
7	13.9	7.4	1.8	41.9	18.4	71.6	
8	13.6	7.3	1.8	33.9	18.4	64.8	67.1
9	11.6	7.3	1.8	35.0	18.4	64.3	

[a] Preirrigation does not include the 0.4-cm rain that occurred.

[b] To October 31, only rains of intensity greater than 0.25 cm considered.

[c] Total = total water applied (irrigation plus rainfall) from stand establishment to harvest + the final soil-water depletion (plant available water, Table 5).

Table 10. IRRIGATION AND RAINFALL DATA FOR SURFACE PLOTS AT THE INDICATED TIME INTERVALS (1974)

Treat-ment No.	Preirrigation[a] (cm)	Seeding to stand estab. Irrigation (cm)	Seeding to stand estab. Rain (cm)	Stand estab. to harvest Irrigation (cm)	Stand estab. to harvest Rain[b] (cm)	Total[c] (cm)	
1	16.5	16.0	0	49.4	25.1	86.5	84.9
2	16.5	15.3	0	45.8	25.1	84.3	
3	16.5	15.4	0	47.0	25.1	83.8	
4	16.5	15.4	0	43.9	25.1	82.8	79.1
5	16.5	15.3	0	37.4	25.1	74.5	
6	16.5	15.4	0	43.6	25.1	80.0	
7	16.5	15.4	0	44.9	25.1	81.3	77.5
8	16.5	15.3	0	37.0	25.1	74.6	
9	16.5	15.2	0	40.0	25.1	76.6	

[a] Estimated. The 40.6-cm irrigation to determine hydraulic properties of the soils is not included here.

[b] To October 31, only rains of intensity greater than 0.25 cm considered.

[c] Total = total water applied (irrigation plus rainfall) from stand establishment to harvest + the final soil water depletion (plant available water, Table 5).

Table 11. TOTAL AMOUNTS OF WATER APPLIED IN CM (RAINFALL PLUS IRRIGATION) DURING THE 1972, 1973 AND 1974 GROWING SEASONS COMPARED WITH COMPUTED EVAPOTRANSPIRATION (ET) IN CM. PAN REFERS TO ET AS ESTIMATED BY EVAPORATION PAN AND ISS REFERS TO IRRIGATION SCHEDULING SERVICE ESTIMATES OF ET

Treat-ment No.	1972[a] Applied	1972[a] ET(PAN)	1973[a] Applied	1973[a] ET(ISS)	1974[a] Applied	1974[a] ET(ISS)
1	106.6	55.1	84.1	54.6	86.5	57.9
2	108.5	55.1	85.7	54.6	84.3	58.7
3	102.6	55.1	75.2	54.6	83.8	59.4
4	85.8	55.1	74.2	54.1	82.8	57.9
5	88.7	55.1	78.7	56.6	74.5	56.9
6	82.6	55.1	67.8	54.6	80.0	59.2
7	76.8	55.1	71.6	53.6	81.3	57.9
8	77.2	55.1	64.8	55.6	74.6	59.7
9	73.2	55.1	66.9	54.6	76.6	59.4
Average	89.1	55.1	74.1	54.8	80.5	58.6

[a] Post irrigation rainfall for 1972, 1973 and 1974 are 13.9 cm, 10.6 cm, and 17.4 cm, respectively.

Assuming that deep percolation losses are equal to amounts applied minus estimated ET, these data show that the amounts of water lost by deep percolation varied in 1973 from a high of 36 percent from Treatment 3, to a low of 14 percent from Treatment 8, as estimated by ISS. During the 1974 irrigation season, calculated deep percolation losses were 31 percent from the 80 percent efficiency treatment, and 24 percent from the 100 percent efficiency treatment. Averaged for all treatments, the depths of water lost by deep percolation were 19.3 cm in 1973 and 21.9 cm in 1974 (Table 11). Thus, on the average in 1973 and 1974, 20.6 cm of water was lost over a 5 month period. This amounts to a downward flux of 0.14 cm/day. Since hydraulic gradients were close to one during most of the irrigation season, the flux was approximately equal to the hydraulic conductivity at the prevailing water content. Hydraulic conductivities as small as 0.14 cm/day could not be measured _in situ_. It is also clear from Fig. 2 that, in this range of conductivities, small errors in the determination of water content produced very large errors in estimated fluxes.

From Neutron Probe Data - The water contents in the plots were measured with the neutron probe at short time intervals, particularly during the last year of the three year study. During the 1974 growing season, the water content in each plot was determined more than 45 times. From the differences in water content with time, water use by the crop can be calculated if deep percolation losses are known or are negligibly small. Table 12 lists 1973 and 1974 crop water use as estimated by neutron probe, amounts of water applied (irrigation and rain), and ISS computed ET.

The data in Table 12 show that although the predicted evapotranspiration data are nearly the same for all treatments, the measured water use data show large differences. This table shows that differences in water use measured with the neutron probe are somewhat larger between depletions than between efficiencies, indicating that depletion treatments had more effect on leaching than did efficiency treatments. The cumulative water use estimated by ISS and from neutron probe data in 1974 are also presented in Figures 7, 8 and 9 for the 25, 50 and 75 percent depletion treatments, respectively.

Table 12. COMPARISON OF NEUTRON PROBE MEASURED WATER USE WITH ISS ESTIMATED WATER USE, AND TOTAL WATER ACTUALLY APPLIED FOR 1973 AND 1974

Treatment No.	Depletion %	Efficiency %	1973 Measured (cm)	1973 Applied[a] (cm)	1973 ET(ISS) (cm)	1974 Measured (cm)	1974 Applied[a] (cm)	1974 ET(ISS) (cm)
1	25	80	71.0	94.1	54.6	89.8	86.5	57.9
2	50	80	64.2	85.7	54.6	74.6	84.3	58.7
3	75	80	59.5	75.2	54.6	63.1	83.8	59.6
4	25	90	80.1	74.2	54.1	78.3	83.8	57.9
5	50	90	66.3	78.7	56.6	69.5	74.5	56.9
6	75	90	57.7	67.8	54.6	54.4	80.0	59.2
7	25	100	63.6	71.6	53.6	81.5	81.3	57.9
8	50	100	50.4	64.8	55.6	67.4	74.6	59.7
9	75	100	50.0	64.9	54.6	59.3	76.6	59.4
Mean			62.5	74.1	54.8	70.9	80.5	58.6

a Applied water includes post irrigation rains of 10.6-cm and 17.4-cm for 1973 and 1974, respectively.

Table 13. EFFECT OF DEPLETION AND EFFICIENCY TREATMENT ON MEASURED (NEUTRON PROBE) AND PREDICTED (ISS) WATER USE

Treatments	Depletion%	1973 Measured (cm)	1973 Applied (cm)	1973 ET(ISS) (cm)	1974 Measured (cm)	1974 Applied (cm)	1974 ET(ISS) (cm)
1,4,7	25	71.6	76.6	54.1	83.2	83.5	57.9
2,5,8	50	60.3	76.4	55.6	70.4	77.8	58.4
3,6,9	75	55.7	69.3	54.6	58.9	80.1	59.3
	Efficiency%						
1,2,3	80	64.9	81.7	54.6	75.8	84.9	58.7
4,5,6	90	68.0	73.6	55.1	67.4	79.1	58.0
7,8,9	100	56.7	67.1	54.6	69.4	77.5	59.0

The measured water use (neutron probe) was less than the total amount of water applied. In 1973, the difference between measured use and total water applied was 20 percent and in 1974, the difference was 26 percent. These differences probably arise from systematic errors in water contents as measured with the neutron probe, the plot surfaces not being perfectly level, and rapid drainage losses immediately following heavy irrigation.

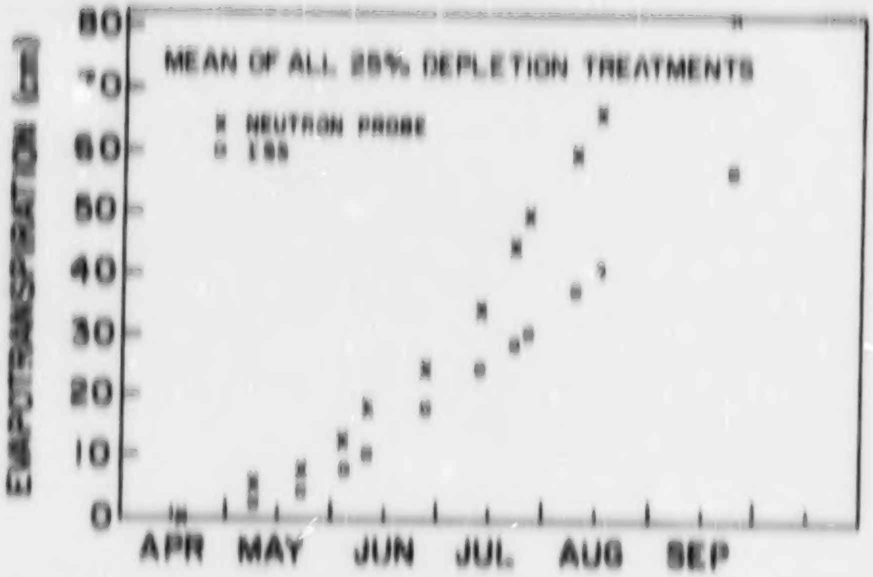

Figure 7. Accumulative evapotranspiration estimated by ISS and smoothed neutron probe data for 1974 (mean of all 25% depletion treatments).

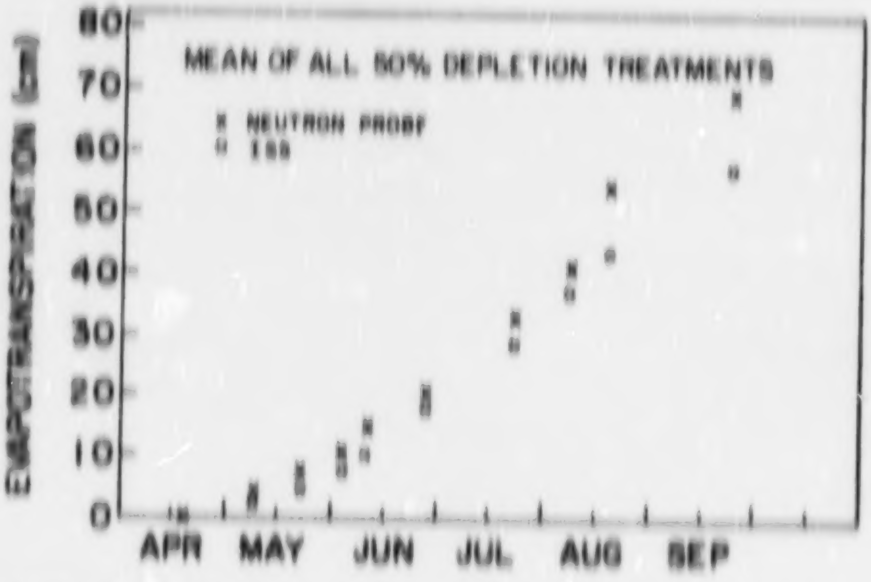

Figure 8. Accumulative evapotranspiration estimated by ISS and smoothed neutron probe data for 1974 (mean of all 50% depletion treatments).

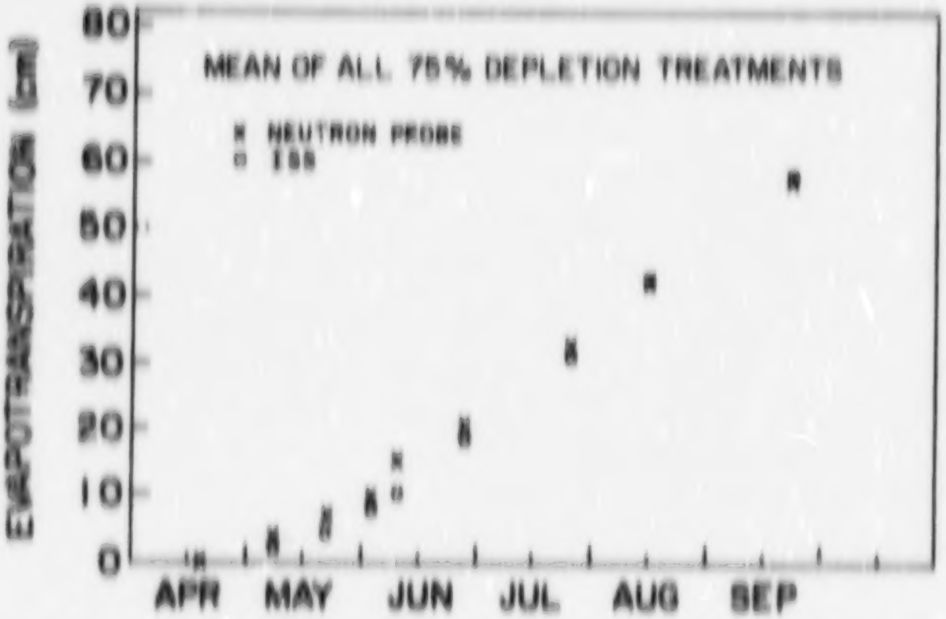

Figure 9. Accumulative evapotranspiration estimated by ISS and smoothed neutron probe data for 1974 (mean of all 75% depletion treatments).

Table 13 indicates that the differences between applied water and measured water depletions were less for the 25 percent depletion treatments than for the 75 percent depletion treatments. Differences between applied and measured values could arise from errors incurred when monitoring soil-water with the neutron probe in stratified soils.

In conclusion, it appears that up to 30 percent of the water applied was lost by deep percolation. In 1973 and 1974, the amounts varied from an average loss of 32 percent for the 80 percent efficiency treatment, to an average loss of 21 percent for the 100 percent efficiency treatment. The data presented also indicate that the allocation of 90 cm of water in 1973 and 1974 by the Rio Grande Irrigation District was more than adequate for growing cotton, and that if the full allocation was used on cotton, extensive percolation losses occurred.

Soil Salinity

Concentration of Saturation Extracts - The results of the analyses of the saturation extracts are presented in Tables 14-19 and in Appendix Tables 1-6.

In Appendix Tables 1-6, electrical conductivities of the saturation extracts (mmhos/cm) are presented.

The data in Tables 14-19 are presented in g per 100 g soil. The amount of salt per 100 g soil was calculated from:

$$\text{g salts/100 g soil} = (\text{ml H}_2\text{O/100 g soil}) \times (\text{g/l})/1000 \qquad (1)$$

where:

$$\text{g/l} = \text{mmhos/cm} \times 14.3 \times 0.07 \qquad (2)$$

A complete chemical analysis was made on the saturation extracts of the soil samples collected during May 1973. From the equivalent weights of the constituent ions in the extracts, an average milliequivalent weight of 0.070 was found for the conversion of meq/l to g/l. By further plotting EC_e (mmhos/cm) versus total salts in milliequivalents per liter, a correlation was obtained between EC_e and concentration in meq/l (Figure 10), with a slope of 14.3.

An analysis of variance based on saturation extracts of soil samples from the surface irrigation treatments is presented in Table 20. The data in Tables 14-19, and Appendix Tables 1-6 show considerable variation in salinity not only with depth, but also in the horizontal plane. The significant variation by depth was expected since the soil profiles are sharply stratified. This stratification is a natural property of these soils, and not under experimental control. An index of variation is the standard deviation about the mean soil salinity. For depths greater than 100 cm, the standard deviation was typically as large as the mean. It may be noted that spatial variation appeared to be greater in the subsoil than in the topsoil.

The large spatial variation in soil salinity (indicated by the large coefficients of variation associated with various error terms) made it difficult to detect any statistically significant differences due to irrigation treatments.

Table 20 shows that the only factors having a significant effect on soil salinity were depth and the year X depletion interaction. Soil salinity was independent of the efficiency treatments, which was not too surprising considering the relatively small differences in the amounts of water applied on the three efficiency treatments and the extreme natural variability of the experimental site. Although depletion was not significant, the data in Table

Table 14. SALT CONTENT OF SOIL (g/100g OF SOIL) IN SURFACE-IRRIGATED PLOTS 1-10 AND OUTSIDE SURFACE-IRRIGATED PLOTS 11-30 (SPRING 1972 PRIOR TO PLANTING)

	Depth (cm)			
Plot No.	0-20	20-40	40-60	60-90
P 1	.13	.15	.44	.06
P 2	.19	.22	.29	.02
P 3	.15	.32	.50	.06
P 5	-	-	-	-
P 6	.11	.18	.40	.11
P 7	.20	.38	.39	.15
P 8	.18	.29	.35	.39
P 9	.13	.16	.29	.18
P10	.35	.55	.41	.28
P11S[a]	.21	.40	.57	.15
P12S	.23	.33	.33	.08
P13S	.21	.18	.29	-
P14S	.20	.44	.32	.19
P15S	.13	.19	.36	.12
P16S	.13	.19	.30	.13
P17S	.14	.22	.43	.14
P18S	.21	.38	.43	.10
P19S	.21	.39	.60	.25
P21S	.07	.08	.05	.04
P22S	.07	.05	.03	.02
P23S	.12	.06	.03	-
P24S	.15	.15	.39	.15
P25S	.36	.46	.37	.45
P26S	.22	.41	.46	.37
P27S	.23	.35	.54	.18
P28S	.19	.30	.53	.30
P29S	.16	.23	.34	.43
Mean	.18	.29	.37	.18
Std. Dev.	.069	.15	.15	.13

[a] S designates south of plot.

Table 15. SALT CONTENT OF SOIL ($g/100_g$ OF SOIL) IN FURROW-IRRIGATED PLOTS (DECEMBER 1972)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
P 1	0.09	0.17	0.34	0.29	0.12	0.06	0.03	0.03
P 2	0.08	0.13	0.39	0.20	0.10	0.06	0.05	0.05
P 3	0.10	0.20	0.41	0.44	0.18	0.07	0.06	0.10
P 5	0.06	0.12	0.17	0.15	0.12	0.05	0.04	0.03
P 6	0.08	0.15	0.36	0.41	0.11	0.09	0.05	0.04
P 7	0.12	0.16	0.27	0.26	0.14	0.06	0.04	0.03
P 8	0.09	0.15	0.41	0.30	0.14	0.05	0.05	0.06
P 9	0.13	0.23	0.46	0.41	0.19	0.11	0.06	0.05
P10	0.16	0.28	0.51	0.41	0.22	0.15	0.12	0.12
P11	0.11	0.21	0.37	0.42	0.13	0.08	0.06	0.12
P12	0.16	0.30	0.41	0.36	0.13	0.07	0.05	0.04
P13	0.15	0.32	0.50	0.33	0.11	0.08	0.07	0.06
P14	0.11	0.24	0.41	0.23	0.14	0.07	0.02	0.04
P15	0.13	0.28	0.54	0.21	0.11	0.06	0.05	0.05
P16	0.09	0.18	0.36	0.25	0.09	0.04	0.03	0.02
P17	0.11	0.17	0.45	0.31	0.05	0.03	0.03	0.03
P18	0.10	0.15	0.34	0.31	0.15	0.05	0.05	0.05
P20	0.09	0.21	0.35	0.42	0.23	0.11	0.09	0.06
P21	0.12	0.15	0.11	0.09	0.04	0.08	0.20	0.02
P22	0.07	0.14	0.17	0.13	0.05	0.06	0.04	0.04
P23	0.09	0.15	0.12	0.10	0.09	0.10	0.07	0.02
P24	0.22	0.26	0.48	0.39	0.27	0.31	0.42	0.04
P25	0.20	0.24	0.39	0.38	0.23	0.39	0.29	0.03
P26	0.24	0.33	0.44	0.43	0.30	0.45	0.16	0.29
P27	0.11	0.17	0.33	0.28	0.18	0.17	0.11	0.10
P29	0.13	0.15	0.33	0.32	0.23	0.15	0.06	0.05
P30	0.11	0.11	0.22	0.23	0.13	0.07	0.04	0.03
Mean	0.12	0.19	0.36	0.30	0.16	0.11	0.082	0.060
Std.Dev.	0.043	0.062	0.12	0.12	0.090	0.11	0.086	0.055

Table 16. SALT CONTENT OF SOIL (g/100g OF SOIL) IN SURFACE-IRRIGATED PLOTS (MAY 1973)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
P 1	0.07	0.20	0.29	0.27	0.17	0.09	0.05	0.04
P 2	0.10	0.13	0.36	0.29	0.26	0.13	0.13	0.07
P 3	0.10	0.15	0.29	0.47	0.16	0.08	0.06	0.05
P 5	0.06	0.07	0.09	0.12	0.06	0.03	0.02	0.02
P 6	0.09	0.07	0.12	0.27	0.10	0.03	0.05	0.03
P 7	0.06	0.07	0.16	0.27	0.10	0.05	0.06	0.05
P 8	0.09	0.09	0.20	0.43	0.23	0.19	0.08	0.07
P 9	0.11	0.11	0.20	0.40	0.26	0.16	0.10	0.06
P10	0.10	0.12	0.28	0.45	0.22	0.08	0.06	0.08
P11	0.13	0.18	0.15	0.70	0.34	0.07	0.07	0.07
P12	0.13	0.10	0.36	0.55	0.15	0.07	0.06	0.04
P13	0.15	0.14	0.50	0.31	0.19	0.09	0.06	0.05
P14	0.09	0.08	0.30	0.36	0.14	0.05	0.04	0.10
P15	0.10	0.12	0.26	0.40	0.15	0.05	0.05	0.04
P16	0.10	0.09	0.58	0.16	0.16	0.06	0.02	0.03
P17	0.13	0.14	0.26	0.32	0.16	0.07	0.05	0.05
P18	0.11	0.16	0.37	0.51	0.21	0.07	0.05	0.04
P20	0.09	0.09	0.31	0.37	0.21	0.08	0.05	0.07
P21	0.11	0.09	0.11	0.09	0.09	0.12	0.07	0.04
P22	0.10	0.08	0.07	0.08	0.09	0.13	0.10	0.03
P23	0.10	0.12	0.20	0.10	0.12	0.14	0.11	0.05
P24	0.17	0.35	0.24	0.36	0.42	0.43	0.31	0.10
P25	0.13	0.17	0.40	0.40	0.28	0.43	0.25	0.20
P26	0.15	0.22	0.26	0.49	0.60	0.31	0.48	0.28
P27	0.11	0.10	0.31	0.65	0.41	0.20	0.28	0.33
P29	0.10	0.11	0.23	0.46	0.45	0.36	0.26	0.45
P30	0.12	0.15	0.19	0.39	0.26	0.13	0.08	0.06
Mean	0.11	0.13	0.26	0.36	0.22	0.14	0.11	0.082
Std.Dev.	0.025	0.058	0.12	0.15	0.13	0.11	0.11	0.10

Table 17. SALT CONTENT OF SOIL (g/100g OF SOIL) IN SURFACE-IRRIGATED PLOTS (DECEMBER 1973)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
P 1	0.08	0.12	0.27	0.24	0.13	0.06	0.02	0.05
P 2	0.10	0.14	0.40	0.31	0.08	0.05	0.06	0.06
P 3	0.10	0.15	0.49	0.30	0.11	0.06	0.05	0.05
P 5	0.11	0.06	0.43	0.29	0.05	0.13	0.13	0.03
P 6	0.07	0.09	0.18	0.23	0.05	0.02	0.02	0.02
P 7	0.06	0.16	0.25	0.31	0.13	0.05	0.05	0.04
P 8	0.10	0.14	0.33	0.38	0.17	0.06	0.05	0.06
P 9	0.11	0.14	0.33	0.32	0.30	0.08	0.05	0.04
P10	0.13	0.23	0.48	0.38	0.12	0.07	0.09	0.07
P11	0.19	0.21	0.52	0.39	0.14	0.06	0.07	0.04
P12	0.12	0.15	0.61	0.48	0.14	0.05	0.05	0.15
P13	0.15	0.18	0.47	0.54	0.14	0.08	0.08	0.07
P14	0.05	0.16	0.35	0.17	0.11	0.03	0.03	0.04
P15	0.12	0.15	0.31	0.25	0.12	0.05	0.04	0.04
P16	0.10	0.11	0.43	0.27	0.10	0.05	0.03	0.03
P17	0.12	0.18	0.42	0.31	0.17	0.07	0.05	0.04
P18	0.17	0.31	0.29	0.38	0.10	0.05	0.05	0.05
P20	0.18	0.25	0.50	0.38	0.15	0.08	0.04	0.04
P21	0.13	0.13	0.28	0.15	0.24	0.16	0.11	0.03
P22	0.09	0.18	0.06	0.08	0.08	0.09	0.05	0.03
P23	0.09	0.12	0.12	0.07	0.10	0.13	0.07	0.02
P24	0.13	0.15	0.28	0.44	0.05	0.14	0.05	0.03
P25	0.23	0.35	0.38	0.44	0.56	0.55	0.50	0.21
P26	0.25	0.33	0.44	0.48	0.48	0.54	0.38	0.09
P27	0.15	0.21	0.42	0.40	0.29	0.14	0.04	0.03
P29	0.10	0.11	0.23	0.40	0.44	0.36	0.27	0.43
P30	0.13	0.16	0.19	0.38	0.74	0.14	0.07	0.05
Mean	0.13	0.17	0.35	0.33	0.17	0.12	0.088	0.068
Std. Dev.	0.048	0.069	0.14	0.13	0.13	0.14	0.11	0.084

Table 18. SALT CONTENT OF SOIL ($g/100_g$ OF SOIL) IN SURFACE-IRRIGATED PLOTS (DECEMBER 1974)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
P 1	0.08	0.15	0.24	0.39	0.25	0.05	0.03	0.03
P 2	0.13	0.26	0.36	0.26	0.06	0.06	0.06	0.03
P 3	0.09	0.21	0.40	0.33	0.12	0.06	0.05	0.06
P 5	0.11	0.17	0.37	0.28	0.09	0.01	0.03	0.06
P 6	0.10	0.17	0.39	0.33	0.06	0.02	0.02	0.02
P 7	0.08	0.16	0.26	0.31	0.39	0.09	0.06	0.05
P 8	0.08	0.19	0.40	0.42	0.10	0.05	0.06	0.05
P 9	0.07	0.15	0.35	0.34	0.20	0.10	0.06	0.05
P10	0.11	0.26	0.36	0.37	0.24	0.06	0.05	0.04
P11	0.17	0.25	0.33	0.35	0.25	0.11	0.04	0.03
P12	0.17	0.26	0.35	0.43	0.12	0.06	0.04	0.05
P13	0.21	0.31	0.42	0.40	0.16	0.08	0.11	0.13
P14	0.11	0.17	0.32	0.31	0.14	0.03	0.03	0.03
P15	0.10	0.27	0.26	0.33	0.21	0.21	0.19	0.05
P16	0.14	0.38	0.28	0.40	0.13	0.06	0.03	0.02
P17	0.11	0.24	0.39	0.39	0.19	0.10	0.08	0.04
P18	0.17	0.28	0.40	0.47	0.12	0.05	0.05	0.04
P20	0.10	0.23	0.35	0.41	0.14	0.06	0.06	0.03
P21	0.29	0.18	0.27	0.17	0.14	0.14	0.11	0.03
P22	0.08	0.13	0.16	0.13	0.10	0.11	0.10	0.08
P23	0.05	0.13	0.24	0.10	0.10	0.13	0.09	0.02
P24	0.10	0.26	0.29	0.29	0.12	0.12	0.05	0.01
P25	0.20	0.29	0.36	0.39	0.40	0.44	0.43	0.42
P26	0.28	0.40	0.46	0.49	0.43	0.47	0.36	0.10
P27	0.13	0.32	0.44	0.51	0.40	0.17	0.06	0.03
P29	0.08	0.21	0.21	0.45	0.24	0.26	0.08	0.06
P30	0.11	0.28	0.36	0.51	0.20	0.07	0.05	0.03
Mean	0.13	0.23	0.34	0.36	0.19	0.12	0.083	0.059
Std. Dev.	0.059	0.066	0.080	0.11	0.12	0.11	0.097	0.076

Table 19. SALT CONTENT OF SOIL (g/100g OF SOIL) UNDER SURFACE-IRRIGATED PLOTS (DECEMBER 1974)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
P 1E[a]	0.26	0.25	0.42	0.13	0.04	0.04	0.04	0.04
P 3E	0.36	0.21	0.35	0.16	0.15	0.05	0.05	-
P 5E	0.14	0.18	0.31	0.16	0.06	-	-	-
P 7E	0.19	0.17	0.31	0.20	0.10	0.05	0.08	0.04
P 9E	0.28	0.31	0.41	0.28	0.22	0.13	0.05	-
P11E	0.34	0.31	0.42	0.36	0.43	0.40	0.21	0.02
P13E	0.34	0.35	0.46	0.51	0.27	0.10	0.07	0.07
P15E	0.19	0.22	0.27	0.26	0.08	0.03	0.06	0.07
P17E	0.20	0.18	0.33	0.13	0.10	0.03	0.03	0.04
P19E	0.26	0.23	0.38	0.21	0.08	0.04	0.04	0.05
P21E	0.10	0.09	0.08	0.07	0.06	0.05	0.01	0.01
P23E	0.16	0.10	0.06	0.06	0.06	0.06	0.02	0.02
P25E	0.11	0.11	0.06	0.06	0.05	0.06	0.03	0.01
P27E	0.16	0.12	0.06	0.05	0.07	0.07	0.04	0.02
P29E	0.30	0.35	0.43	0.43	0.40	0.32	0.28	0.11
Mean	0.23	0.21	0.29	0.21	0.15	0.10	0.072	0.042
Std. Dev.	0.085	0.088	0.15	0.14	0.14	0.11	0.075	0.029

[a] E designates east of plot.

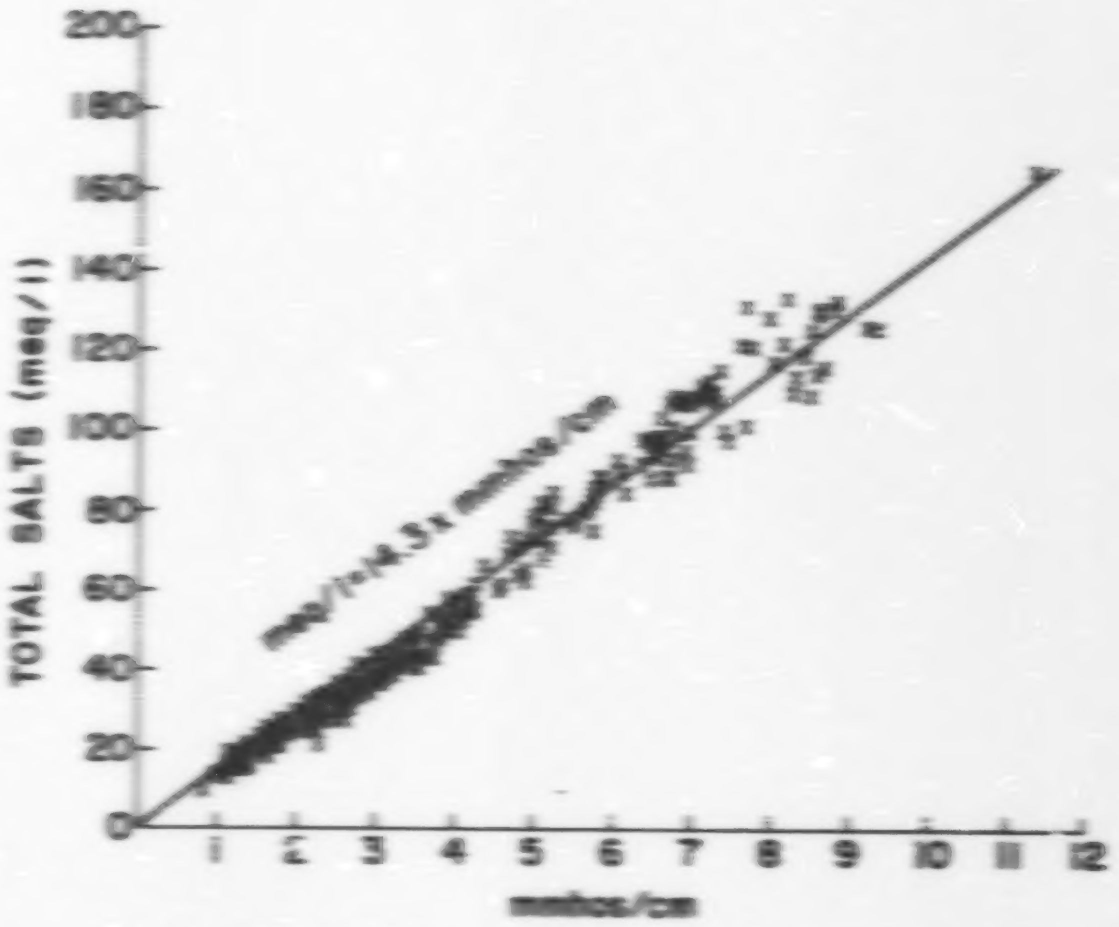

Figure [illegible]. EC_e (mmhos/cm) versus total salts (meq/l) for saturation extracts of field plot samples taken in May 1973.

Table 20. ANALYSIS OF VARIANCE FOR SOIL SALINITY BASED ON SATURATION EXTRACTS FROM THE SURFACE-IRRIGATED PLOTS (FALL SAMPLES 1972, 1973 AND 1974)

Source of Variation	Degrees of freedom	F. Value
Replication	2	-
Years (Y)	2	1.016
Error A	4	c.v. = 49.18
Depths (D)	7	16.48[b]
Error B	14	c.v. = 131.9
Depletion (Depl)	2	2.062
Efficiency (E)	2	0.4009
Depl X E	4	0.8159
Error C	16	c.v. = 167.5
Y X D	14	2.012
Error D	28	c.v. = 31.92
Y X Depl	4	2.954[a]
Y X E	4	1.344
Y X Depl X E	8	0.6243
Error E	32	c.v. = 49.27
D X Depl	14	1.107
D X E	14	0.9099
D X Depl X E	28	0.7541
Error F	112	c.v. = 46.66
Y X D X Depl	28	0.8311
Y X D X E	28	0.8023
Y X D X Depl X E	56	1.216
Error G	224	c.v. = 29.65

[a], [b] Denotes significance at the 5% and 1% level of probability, respectively. c.v. denotes coefficient of variation (%).

20 show that it had five times the effect that efficiency had. This agrees with what was earlier observed from water use data estimated by neutron probe. Differences between water applied and estimated water use were larger among depletion treatments than among efficiency treatments, indicating that depletion treatments would have more effect on leaching. This trend implies that, for the soils in the study area, it may be possible to control soil salinity by altering the irrigation frequency.

The only factor besides depth having a significant effect on soil salinity was the year X depletion interaction, implying that soil salts accumulated (or leached) depending on the depletion treatment and the year the treatment was applied. The year X depletion interaction is shown graphically in Figure 11.

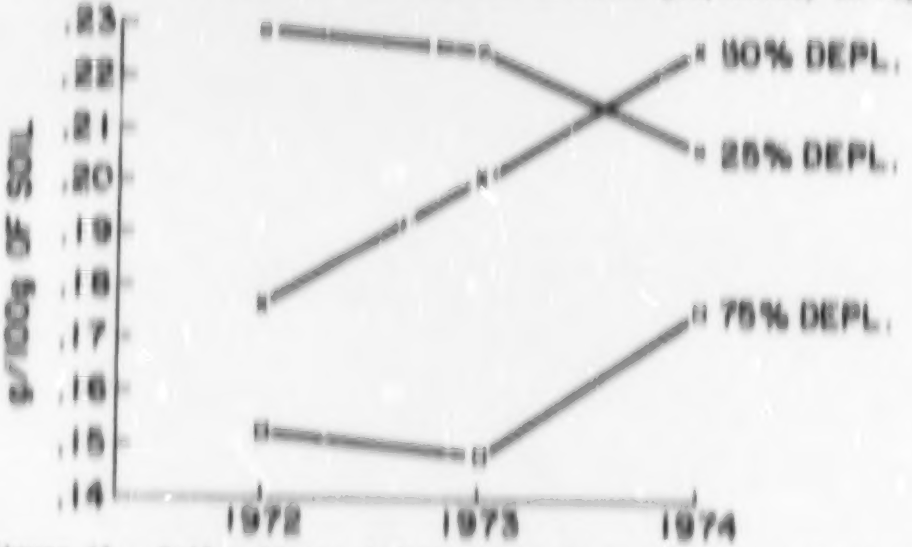

Figure 11. Soil salinity (g/100g of soil) response to depletion and years. Parameters shown are depletion treatments applied.

The strong tendency for salt build-up that occurred at 50 percent depletion indicates that it is possible to increase soil salinity (maintain a positive salt balance) by utilizing proper irrigation management.

The treatment means of the salt contents of the soil after harvest in 1972, 1973 and 1974 are presented in Tables 21, 22 and 23. The three-year treatment means are presented in Table 24.

Table 21. TREATMENT MEANS OF THE SALT CONTENTS OF THE SOIL (g/100g OF SOIL) IN THE SURFACE-IRRIGATED PLOTS (DECEMBER 1972)

Efficiency percent	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All depths
80	.10	.16	.32	.28	.14	.11	.08	.04	.15
90	.12	.20	.37	.31	.15	.10	.10	.06	.18
100	.13	.22	.38	.31	.17	.12	.07	.08	.18
Depletion %									
25	.14	.22	.42	.36	.21	.16	.11	.08	.21
50	.11	.18	.36	.28	.14	.11	.08	.05	.16
75	.10	.18	.30	.26	.11	.07	.06	.05	.14
All treatments	.12	.19	.36	.30	.15	.11	.08	.06	.17

Table 22. TREATMENT MEANS OF THE SALT CONTENTS OF THE SOIL (g/100g OF SOIL) IN THE SURFACE-IRRIGATED PLOTS (DECEMBER 1973)

Efficiency percent	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All depths
80	.12	.15	.35	.29	.18	.15	.12	.10	.18
90	.13	.18	.33	.33	.12	.09	.06	.04	.16
100	.13	.17	.37	.36	.20	.13	.08	.06	.19
Depletion %									
25	.13	.19	.39	.40	.20	.15	.11	.11	.21
50	.13	.18	.36	.33	.21	.13	.09	.06	.19
75	.12	.14	.30	.26	.11	.08	.06	.03	.14
All treatments	.13	.17	.35	.33	.17	.12	.09	.07	.18

Table 23. TREATMENT MEANS OF THE SALT CONTENTS OF THE SOIL (g/100g OF SOIL) IN THE SURFACE-IRRIGATED PLOTS (DECEMBER 1974)

Efficiency percent	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All depths
80	.14	.22	.32	.33	.16	.12	.09	.08	.18
90	.12	.23	.33	.35	.17	.10	.06	.04	.17
100	.14	.24	.35	.39	.25	.15	.10	.06	.21
Depletion %									
25	.14	.24	.33	.38	.17	.14	.08	.04	.19
50	.12	.25	.35	.40	.25	.13	.10	.08	.21
75	.14	.20	.32	.29	.16	.09	.06	.05	.16
All treatments	.13	.23	.33	.36	.19	.12	.08	.06	.19

Table 24. COMBINED TREATMENT MEANS OF THE SALT CONTENTS OF THE SOIL (g/100g OF SOIL) IN THE SURFACE-IRRIGATED PLOTS FOR THE YEARS 1972, 1973 AND 1974

Efficiency percent	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All depths
80	.12	.18	.33	.30	.16	.13	.10	.07	.17
90	.12	.20	.35	.33	.15	.10	.07	.05	.17
100	.13	.21	.37	.36	.21	.13	.08	.07	.20
Depletion %									
25	.14	.22	.38	.38	.20	.13	.10	.08	.21
50	.12	.20	.36	.35	.20	.12	.09	.06	.19
75	.12	.18	.30	.27	.13	.08	.06	.04	.15
All treatments	.13	.20	.35	.33	.17	.12	.08	.06	.18

The mean salt contents for each year are presented in Table 25. Included in this table are the mean salt contents of the samples taken outside of the plots at the beginning of the experiment and at the end of the experiment. This table shows relatively small changes in total salt content of the profiles over the duration of the project. This is probably due to precipitation and to leaching of salts below the 160-cm depths.

Table 25. MEAN SALT CONTENTS (g/100g OF SOIL) FOR THE SURFACE-IRRIGATED PLOTS BY DEPTH FOR EACH SAMPLING PERIOD

	Depth (cm)								
	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160	All depths
[a]Spring '72	.18	.29	.37	.18	-	-	-	-	-
Fall, '72	.12	.19	.36	.30	.16	.11	.08	.06	.17
Spring '73	.11	.13	.25	.36	.22	.14	.11	.09	.18
Fall, '73	.13	.17	.35	.33	.17	.12	.09	.07	.18
Fall, '74	.13	.23	.34	.36	.19	.12	.08	.06	.19
[b]Fall, '74	.23	.21	.29	.21	.15	.10	.07	.04	.16

[a] Soil samples taken within surface irrigated plots 1-10 and outside of surface-irrigated plots 11-30.

[b] Soil samples taken outside of plots.

Composition of Saturation Extracts - The saturation extracts made from soil samples taken during May 1973 were analysed for chemical composition (a total of 2904 independent chemical determinations). The results, presented in appendix Tables 7-14, are summarized in Tables 26-28. Table 26 presents the mean composition of the saturation extracts of soil samples from the first two rows of plots. Table 27 presents the mean composition of the saturation extracts of soil samples from all surface-irrigated plots, and Table 28 presents some of the means from Table 27 together with their standard deviations. This table shows the large variation in chemical composition between plots as evidenced by the large standard deviations. In general, the data show a large increase in soluble salts with depth to about 100 cm, and then a decrease.

The mean quantities of water which were used for making the saturation extracts are presented in column two of Tables 26 and 27. The amounts vary from 83 ml per 125 g of soil at 40-60 cm (clay-loam) to 26 ml per 125 g of soil at 140-160 cm. Since the clay loam and sand have bulk densities of 1.4 and 1.5,

Table 26. MEAN COMPOSITION OF SATURATION EXTRACTS (meq/l) OF SOILS FROM PLOTS 1-20, IRRIGATED BY SURFACE FLOODING (MAY 1973)

Depth (cm)	ml/125g of soil	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	71.6	1.8	23.1	9.3	2.4	10.5	1.0	2.5	0	11.7	8.9	0.1
20-40	73.1	1.9	25.3	8.8	2.7	12.9	0.9	2.1	0	10.6	12.1	0.1
40-60	83.4	4.1	58.5	25.3	7.8	24.3	1.1	3.1	0	8.4	45.2	0.1
60-80	70.8	6.4	94.2	41.6	13.4	38.0	1.2	5.9	0	7.4	79.3	0.6
80-100	28.3	7.6	108.9	41.6	15.2	50.8	1.3	14.1	0	7.1	83.4	3.6
100-120	25.0	4.0	54.2	19.8	6.1	27.5	0.8	7.0	0	6.6	39.0	1.2
120-140	25.7	2.9	36.2	11.6	3.8	19.9	0.7	4.9	0	5.8	24.7	0.9
140-160	25.9	2.7	33.3	11.7	3.3	17.7	0.7	4.3	0	5.9	22.4	0.7

Table 27. MEAN COMPOSITION OF SATURATION EXTRACTS (meq/l) OF SOILS FROM PLOTS 1-30, IRRIGATED BY SURFACE FLOODING (MAY 1973)

Depth (cm)	ml/125g of soil	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	70.8	1.9	24.7	9.9	2.6	11.1	1.0	2.6	0	12.2	9.7	0.1
20-40	73.1	2.1	28.5	10.7	3.0	13.9	1.0	2.6	0	11.3	13.7	0.1
40-60	78.0	4.1	58.0	25.5	7.6	23.6	1.2	3.7	0	9.8	43.1	0.1
60-80	69.6	6.2	90.5	39.7	12.9	36.7	1.3	6.5	0	8.4	73.7	0.7
80-100	38.0	7.1	102.3	36.9	14.2	46.9	1.3	12.6	0	8.3	77.0	2.8
100-120	34.9	4.6	62.0	23.6	7.3	30.4	1.0	8.5	0	7.7	43.6	1.3
120-140	33.6	3.6	48.1	17.7	5.4	24.1	0.9	6.4	0	7.0	33.0	0.9
140-160	30.6	3.3	43.5	16.3	4.6	21.6	0.8	5.9	0	6.7	29.1	0.7

Table 23. MEANS AND STANDARD DEVIATIONS OF IONIC COMPOSITION OF SATURATION EXTRACTS OF SOILS FROM PLOTS 1-30, IRRIGATED BY SURFACE FLOODING (MAY 1973)

	0-20		60-80		140-160	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
EC_e, mmhos/cm	1.9	0.5	6.2	1.7	3.3	1.8
Cations	24.7	6.2	90.5	26.1	42.5	[illegible]
Ca (meq/l)	9.9	3.0	30.7	13.7	36.5	14.7
Mg (meq/l)	2.6	0.8	12.9	4.5	4.6	3.6
Na (meq/l)	11.1	2.7	36.7	11.8	21.6	12.2
K (meq/l)	1.0	0.2	1.3	0.3	0.8	0.4
Cl (meq/l)	2.6	0.6	6.5	3.6	5.9	4.0
CO_3 (meq/l)	0	0	0	0	0	0
HCO_3 (meq/l)	12.2	3.2	0.4	2.7	6.7	2.3
SO_4 (meq/l)	9.7	4.1	73.0	25.7	20.1	24.0
NO_3 (meq/l)	0.1	0.2	0.7	0.9	0.7	1.3

respectively, and average field water contents of 40 percent and 8 percent, respectively, factors of 2.2 and 3.9 were obtained for converting extract concentrations to field concentrations for these two soils. Converting the anion and cation concentrations to field moisture contents, it was found that the large salt concentration at the 60- to 100-cm depth, as compared with salt concentration of the sand, was mainly due to higher concentrations of Ca, Mg and SO_4. The latter concentrations at the 60- to 100-cm depth were about double those at the 120- to 140-cm depth. The concentrations of the other anions and cations at those two depths were about the same.

It appeared that there was considerable gypsum present at the 60- to 100-cm depth at the interface between the clay-loam and sand. Whether this gypsum originated from the soil or from the irrigation water was not clear. If it could be shown that the gypsum in irrigation water does precipitate at or above the clay-sand interface in layered soil profiles, this would be of considerable interest in studying the quality of irrigation return flow. Such a process would reduce the total salt concentration of the return flow. On the other hand, precipitation of gypsum has a negative effect on the sodium adsorption ratio of the soil solution. For example, after converting to field water contents, the SAR of the soil solution at 60-80 cm was 10.7, but at 120-140 cm it was 14.0, considerably higher.

Quality of Percolation Water

Composition of Soil Solution - The electrical conductivities of soil solution samples withdrawn with suction cups in 1972, 1973 and 1974 are presented in Appendix Tables 15, 16 and 17. Because of the low water content of the sandy subsoil and the very low hydraulic conductivity of the soil around the cups, suction often had to be applied for several days in order to get a sufficient sample volume for chemical analysis. No samples were obtained from some of the suction cups.

The data from the January - April 1973 sampling period were almost complete. During this period, all plots were irrigated with 60 cm of water then covered with plastic in order to determine hydraulic conductivity of the subsoil. As a result, the subsoil was relatively wet, and a suction sample could be obtained from all plots. A complete chemical analysis was made of these samples.

For each plot, electrical conductivities of soil solution samples taken during the year are presented along with the mean conductivity and standard deviation for all plots (Tables 29, 30 and 31). The average chemical composition of the soil solution samples withdrawn from the subsoil in the period January through April 1973 is presented in Table 32, together with the composition of the water from the irrigation well. The data in Tables 29-32 show that the average electrical conductivity of samples removed through the suction cups during the three years of study was 7.89 mmhos/cm, which is 6.5 times higher than the salt concentration from the irrigation well. Rhoades et al. (1973) presented compositions of drainage waters from lysimeters irrigated with synthesized river waters from the Western U.S.A. Since, after multiplication by a factor of 1.4, their water No. 3 is almost identical in composition to the well water used in the present experiment, we may compare their results with ours. Rhoades et al. (1973) measured the salt concentration of the drainage water from the lysimeters irrigated with No. 3 water at leaching fractions of 0.1, 0.2 and 0.3. At these leaching fractions, their observed ratios of EC_{dw}/EC_{iw} were 6.2, 3.6 and 2.9, respectively. Inasmuch as the average ratio of EC_{dw}/EC_{iw} for our field plots is 6.5, it appears that, based on this data, the fraction of applied water that percolated to the subsoil was around 10 percent.

The composition of the drainage water as a function of leaching fraction was also presented by Rhoades et al. (1973). Their ratio of the concentration of each ion in the drainage water to the concentration of each ion in the irrigation water was different in each case. Nevertheless, their ratios obtained from the lysimeters irrigated at a leaching fraction of between 0.1 and 0.2 were very similar to the ratios obtained for the various ions in the present field experiment.

Based on this information, it appears that the leaching fraction on the field plots has averaged between 0.1 and 0.2 during the past three years. On the average then, 15 percent of the applied water should have percolated to the subsoil. This is considerably less than that computed from neutron probe data and from climatological data. Work presently underway will hopefully provide data to reconcile these differences in the estimation of the fraction of the water that actually percolated to the subsoil.

Table 29. MEAN ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION SAMPLES (1972 CROPPING SEASON) AND OF SATURATION EXTRACTS OF SAMPLES TAKEN AT SIMILAR DEPTHS IN THE SOIL PROFILE OF THE SURFACE-IRRIGATED PLOTS (DECEMBER 1972)

Plot No.	EC (mmhos/cm) of soil solution	EC_e (mmhos/cm) of saturation extract	Ratio
1	7.9	1.36	5.81
2	10.3	1.74	5.92
3	–	2.68	–
5	8.7	1.66	5.24
6	5.5	2.12	2.59
7	4.8	1.48	3.24
8	6.3	2.06	3.06
9	–	2.66	–
10	12.0	5.58	2.15
11	9.9	6.12	1.62
12	11.5	1.82	6.32
13	–	3.10	–
14	6.5	1.52	4.28
15	11.2	2.06	5.44
16	7.2	1.16	6.21
17	7.8	1.26	6.19
18	9.4	2.08	4.52
20	12.8	2.62	4.88
21	3.0	0.82	3.66
22	2.0	1.26	1.59
23	4.6	1.02	4.51
24	–	1.52	–
25	5.4	1.44	3.75
26	8.9	3.44	2.59
27	10.7	2.61	4.10
29	9.5	2.34	4.06
30	11.3	1.74	6.49
Mean, plots 1-20	8.79	2.39	4.50
Std. Dev. plots 1-20	2.48	1.37	
Mean, plots 1-30	8.14	2.19	4.27
Std. Dev. plots 1-30	2.98	1.24	

Table 30. MEAN ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION SAMPLES (1973 CROPPING SEASON) AND OF SATURATION EXTRACTS OF SAMPLES TAKEN AT SIMILAR DEPTHS IN THE SOIL PROFILE OF THE SURFACE-IRRIGATED PLOTS (DECEMBER 1973)

Plot No.	EC (mmhos/cm) of soil solution	EC_e (mmhos/cm) of saturation extract	Ratio
1	9.6	1.50	6.40
2	10.8	2.62	4.12
3	-	2.32	-
5	7.3	1.16	6.29
6	5.5	0.98	5.51
7	8.0	2.00	4.00
8	8.8	2.16	4.07
9	8.8	2.36	3.73
10	11.3	4.26	2.65
11	9.9	1.98	5.00
12	13.8	6.48	2.13
13	10.0	3.16	3.16
14	4.5	1.82	2.47
15	7.7	1.96	3.93
16	9.6	1.12	8.57
17	9.1	1.78	5.11
18	8.5	1.92	4.43
20	7.8	1.08	9.04
21	6.5	1.40	3.21
22	4.5	1.10	4.00
23	4.9	0.86	5.83
24	2.5	1.50	1.67
25	6.6	6.88	0.93
26	5.2	3.50	1.49
27	7.0	1.22	5.76
29	12.9	6.98	1.85
30	6.5	2.62	2.48
Mean plots 1-20	8.88	2.29	4.48
Std. Dev., plots 1-20	2.16	1.70	
Mean plots 1-30	7.89	2.49	3.98
Std. Dev., plots 1-30	2.76	1.73	

Table 31. MEAN ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION SAMPLES (1974 CROPPING SEASON) AND OF SATURATION EXTRACTS OF SAMPLES TAKEN AT SIMILAR DEPTHS IN THE SOIL PROFILE OF THE SURFACE-IRRIGATED PLOTS (DECEMBER 1974)

Plot No.	EC (mmhos/cm) of soil solution	EC_e (mmhos/cm) of saturation extract	Ratio
1	9.7	1.30	7.46
2	8.1	1.66	4.88
3	–	1.51	–
5	8.4	1.58	5.32
6	4.5	1.10	4.09
7	9.0	1.73	5.20
8	9.5	1.85	5.08
9	8.7	2.52	3.45
10	7.3	2.34	3.12
11	8.4	1.44	5.83
12	6.5	2.24	2.90
13	10.3	4.28	2.41
14	4.6	1.21	3.80
15	7.6	2.49	3.05
16	6.9	1.42	4.86
17	10.3	2.15	4.79
18	8.2	1.88	4.36
20	6.2	1.36	4.56
21	4.0	1.54	2.60
22	3.5	2.68	1.31
23	5.0	0.91	5.49
24	3.0	0.68	4.41
25	7.8	6.34	1.23
26	8.4	3.86	2.18
27	5.6	1.41	3.97
29	6.8	2.92	2.33
30	20.0	1.45	16.32
Mean plots 1-20	7.88	1.89	4.42
Std Dev., plots 1-20	1.75	0.74	
Mean, plots 1-30	7.65	2.07	4.36
Std Dev., plots 1-30	3.38	1.19	

Table 32. AVERAGE CHEMICAL COMPOSITION OF SOIL SOLUTION EXTRACTED FROM THE SURFACE-IRRIGATED PLOTS THROUGH SUCTION CUPS DURING THE PERIOD JANUARY THROUGH APRIL 1973, AND CHEMICAL COMPOSITION OF IRRIGATION WATER, MEAN VALUES (SEE APPENDIX TABLE 23)

	Mean concentration of the solution at 120-150 cm	Standard deviation	Concentration irrigation water
EC x 10^3, mmhos/cm	8.23	3.02	1.22
pH	-	-	7.7
Ca, meq/l	29.0	9.0	5.7
Mg, meq/l	15.5	5.9	1.7
Na, meq/l	52.9	27.6	5.5
K, meq/l	0.6	0.3	0.3
Cl, meq/l	37.6	21.9	2.5
CO_3, meq/l	-	-	0.2
HCO_3, meq/l	5.9	1.0	5.0
SO_4, meq/l	36.2	16.1	3.6
NO_3, ppm	302	200	0.8
PO_4, ppm	0.0	-	-
Sum cations	98.0		13.1
Sum anions	87.8		13.3

The data in Tables 29, 30 and 31 show much variation in the electrical conductivity of the soil solution for different plots and sampling periods. The reason for the large variation in soil salinity between plots is not clear. It is probably a result of the variation in physical and chemical properties of the soil material within the plot area. The electrical conductivities of saturation extracts of soil samples taken at the depths of the suction cups as well as the ratio of conductivity of soil solution to conductivity of saturation extract are shown in Tables 29-31. The average ratio of EC/EC_e for all three years was 4.2 which is within the range of values given in the U.S. Salinity Handbook for medium to coarse textured soils.

The analysis of variance for the electrical conductivities (mmhos/cm) of the soil solution samples, as listed in Tables 29, 30 and 31, is presented in Table 33. The treatment means for depletion are presented in Table 34. The only significant effect among treatments was the depletion treatment. Thus, the salt concentration of the percolation water from the 75 percent depletion plots was significantly lower than that from the 25 and 50 percent depletion plots. This observation agrees with what was earlier observed for total salt in the soil profile, i.e., that depletion had five times the effect in changing the salt concentration of the soil profile that efficiency had.

There are several possible reasons for this result. First of all, the differences in the amounts of water applied to the 80, 90 and 100 percent design efficiency treatments are not large as a result of rainfall and pre-irrigation being the same for all treatments. On the other hand, the spatial variability in salinity and soil physical properties on the experimental site was quite large. Therefore, a larger number of replications was necessary to obtain significant differences than originally anticipated. Secondly, the soil at the experimental site cracks considerably upon drying. This cracking was much more pronounced on the less-frequently irrigated plots. Water percolation through these cracks could have reduced the soil salinity in the subsoil of the 75 percent irrigation depletion treatment. On the 50 percent depletion treatment, cracking was less evident, while the soil in the 25 percent depletion treatment appeared moist during most of the irrigation season and did not crack to any extent. A third reason could be the effect of differences in leaching efficiency on frequently versus less frequently irrigated plots.

The data in Table 32 show that the nitrate concentration of the deep percolation water is relatively high at 8.1 meq/l or 502 ppm. High rates of fertilization and the lack of reducing conditions were the most probable reasons for this, as nitrate concentrations in the saturated zone and in the Del Rio Drain were considerably lower. The relatively high standard deviation about the mean for the various ions in the soil solution suction samples is again due to the large variation in the physical and chemical properties of the soil material over the plot area.

Table 33. ANALYSIS OF VARIANCE FOR ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION SAMPLES AS LISTED IN TABLES 29, 30 AND 31

	Degrees of freedom	MS	F
Total	80-6=74		
Replication	2	23.326	–
Years	2	1.450	0.3229
Error A	4	4.490	C.V. = 26.91%
Depletion	2	46.229	3.7898[a]
Year x depletion	4	16.023	1.314
Efficiency	2	10.479	0.85907
Year x efficiency	4	5.6012	0.4592
Depletion x efficiency	4	6.6083	0.5417
Error B	16	12.1981	C.V. = 44.35%
Year x depletion x efficiency	8	3.7105	0.5535
Error C	32-6=26	6.70300	C.V. = 32.88%

[a] Significant at the 5% level of probability.

Note: degrees of freedom for Error C reduced by 6 to correct for the 6 missing values.

Table 34. TREATMENT MEANS OF THE ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF THE SOIL SOLUTION SAMPLES EXTRACTED THROUGH SUCTION CUPS IN 1972, 1973 AND 1974

	Percent depletion		
	25	50	75
1972	9.73	9.12	5.44
1973	8.70	7.80	7.17
1974	6.84	9.53	6.53
Mean	8.42[a]	8.82[a]	6.38[b]

[a,b] Numbers followed by common letter not significantly different.

Water Quality in Test Wells

The electrical conductivities and chemical constituents of waters sampled from the five test wells during 1972, 1973 and 1974 are presented in Appendix Tables 18 through 22. The chemical composition of water from the 20-cm I.D. well used for irrigating the plots is presented in Appendix Table 23.

Table 15. AVERAGE CHEMICAL COMPOSITION (meq/l EXCEPT NO$_3$ in ppm) OF SAMPLES TAKEN FROM TEST WELLS DURING 1972, 1973 AND 1974

Well	Year	Depth (m)	EC×10^3	pH	Total Cations	Total Anions	Ca	Mg	Na	K	Cl	CO$_3$	HCO$_3$	SO$_4$	NO$_3$
							meq/l								ppm
1	1972	22.9	1.14	7.60	11.38	11.71	5.13	1.60	4.67	0.18	2.74	0.26	3.79	4.91	0.09
1	1973	22.9	1.07	7.43	11.10	11.29	5.79	1.54	4.00	0.18	2.72	0.20	3.84	4.51	1.27
1	1974	22.9	1.05	8.04	11.50	11.41	5.58	1.69	3.56	0.17	2.95	0.05	3.64	4.77	0.23
1	Mean	22.9	1.09		11.33	11.47	5.50	1.61	4.06	0.18	2.80	0.17	3.75	4.73	0.53
2	1972	15.5	1.51	7.52	16.40	16.70	8.27	2.23	5.75	0.23	3.46	0.08	6.11	7.05	0.14
2	1973	15.5	1.45	7.37	15.96	16.17	7.89	2.10	5.75	0.22	3.26	0.35	5.90	6.64	1.52
2	1974	15.5	1.37	8.07	15.00	15.36	6.84	1.96	5.98	0.22	2.80	0.08	5.86	6.60	0.34
2	Mean	15.5	1.44		15.81	16.07	7.67	2.10	5.83	0.22	3.17	0.17	5.96	6.76	0.67
3	1972	11.8	1.60	7.46	17.03	17.20	8.00	2.38	6.31	0.24	3.45	0.01	6.35	7.39	0.14
3	1973	11.8	1.49	7.36	16.34	16.35	7.67	2.30	6.33	0.24	3.22	0.32	6.03	6.75	1.55
3	1974	11.8	1.74	8.03	19.37	19.10	9.27	2.70	7.08	0.25	4.46	0.07	5.97	8.60	0.31
3	Mean	11.8	1.61		17.58	17.55	8.28	2.40	6.57	0.24	3.71	0.14	6.12	7.58	0.67
4	1972	8.2	1.46	7.51	15.14	15.44	6.94	2.34	5.63	0.23	3.10	0.02	5.73	6.58	0.00
4	1973	8.2	1.53	7.35	16.97	16.50	7.40	2.59	6.33	0.25	3.13	0.20	6.79	6.35	1.29
4	1974	8.2	1.89	8.03	20.86	21.00	9.72	3.18	8.00	0.27	4.71	0.02	6.45	9.89	0.55
4	Mean	8.2	1.63		17.65	17.67	8.02	2.70	6.60	0.25	3.65	0.08	6.32	7.61	0.61
5	1972	5.8	1.50	7.27	15.64	16.17	6.71	2.94	5.69	0.30	3.31	0.10	5.90	6.70	0.00
5	1973	5.8	1.40	7.41	15.56	14.86	6.80	2.63	5.80	0.30	3.26	0.29	5.80	5.43	1.02
5	1974	5.8	2.00	7.96	22.36	22.30	10.50	3.85	7.64	0.34	5.35	0.02	6.07	10.85	0.79
5	Mean	5.8	1.63		17.86	17.78	8.00	3.14	6.38	0.31	3.97	0.14	5.98	7.66	0.60
Dev.	1972	26.0	1.39	7.85	12.02	12.51	4.75	1.87	5.21	0.29	2.80	0.41	3.65	5.66	0.00
Dev.	1973	26.0	1.28	7.35	13.27	13.86	5.75	1.82	5.49	0.22	2.65	0.20	5.03	6.05	1.67
Dev.	1974	26.0	1.16	7.41	13.15	13.06	5.91	1.55	5.50	0.19	2.39	0.07	5.27	5.20	0.35
Dev.	Mean	26.0	1.28		12.81	13.14	5.47	1.75	5.40	0.20	2.61	0.23	4.65	5.64	0.67

Chemical composition data obtained from each test well and the irrigation well were averaged for each year. The averages are presented in Table 35. The mean chemical composition of the water from the irrigation well was similar to the average chemical composition of the test wells at 15.5 and 22.9 m, indicating that most of the water from the irrigation well was withdrawn from depths in this range.

Cotton Yields and Quality

Yield and Quality for 1974 - 1974 cotton yields are presented in Appendix Table 24 and the cotton quality data for the first and second harvests are presented in Appendix Tables 25-30.

The analysis of variance for cotton yield for the surface irrigated plots is presented in Table 36. 1974 was the first year of the experiment during which both the depletion and efficiency treatments significantly affected cotton yields.

Table 36. ANALYSIS OF VARIANCE FOR COTTON YIELD FOR 1974
(SURFACE-IRRIGATED PLOTS)

Source of variation	Degrees of freedom	F value
Replication	2	
Harvest date	1	1060.[b]
Error A	2	
Percent depletion	2	4.85[a]
Efficiency	2	5.16[a]
Percent depletion x efficiency	4	0.510
Error B	16	
Harvest date x percent depletion	2	1.40
Harvest date x efficiency	2	2.32
Harvest date x percent depletion x efficiency	4	0.738
Error C	16	

Coefficient of variation = 11.9%; mean = 1030 kg/ha.

[a,b] Significant at the 5% and 1% level of probability, respectively.

The average yields for the treatments are presented in Table 37. The average total yield (first harvest + second harvest) was 1030 kg/ha.

This yield was slightly below the 1120 kg/ha average for the New Mexico Experiment Station but considerably higher than the average yield for the Mesilla Valley of 560 to 700 kg/ha. During the 1974 growing season, an infestation of Verticillium wilt was observed to some degree in all plots. The disease was more severe in the trickle plots than in the surface-irrigated plots.

Highest cotton yields were obtained for the 80 percent efficiency treatment and the 50 percent depletion treatment. The lack of a significant depletion X efficiency interaction indicates that the differences in yield due to the efficiency treatments will be similar across all of the depletion treatments.

Table 37. EFFECTS OF IRRIGATION EFFICIENCY AND WATER DEPLETION TREATMENTS ON THE TOTAL YIELDS OF COTTON FOR THE SURFACE-IRRIGATED PLOTS (1974)

Water depletion %	Irrigation efficiency (%) 80	 90	 100	Average
		(kg/ha)		
25	1050	1020	930	1000^a
50	1140	1130	1030	1100^b
75	1080	941	930	986^a
Average	1090^a	1030^{ab}	963^b	1033

Means followed by common letter are not significantly different at the 5% or less level of probability.

Table 38 presents the effects of irrigation efficiency on the yield and quality of cotton from the surface irrigation treatments. The irrigation efficiency treatments significantly affected only yield during the 1974 season.

The effect of varying the soil-water depletion on yield and quality are presented in Table 39. Although the depletion treatments significantly affected the 2.5% span of the second harvest, these yields were so low as to negate any economic differences that may have occurred. The highest micronaire resulted from the 75 percent depletion treatment, but this was opposite to what happened

Table 38. EFFECTS OF IRRIGATION EFFICIENCY ON YIELD AND QUALITY OF COTTON FOR THE SURFACE-IRRIGATED PLOTS (1974)

Irrigation efficiency (%)	Yield kg/ha	Lint %	2.5% span	Unif. ratio	MIC	Strength	Elongation
			1st harvest				
80	890^{a}	37.5	1.19	46.8	4.0	22.2	6.3
90	851^{ab}	37.5	1.17	47.3	3.8	21.7	6.1
100	784^{b}	37.3	1.18	46.6	3.9	21.6	6.2
			2nd harvest				
80	202	38.6	1.18	46.2	3.7	21.2	6.8
90	179	38.4	1.16	46.7	3.7	21.4	6.7
100	179	38.1	1.17	46.1	3.7	21.5	6.6
			1st and 2nd harvests combined				
80	1090^{a}	38.0	1.18	46.5	3.8	21.7	6.6
90	1030^{ab}	38.0	1.17	47.0	3.8	21.6	6.4
100	963^{b}	37.7	1.18	46.3	3.8	21.5	6.4

Means followed by common letter are not significantly different at the 5% or less level of probability.

Table 39. EFFECTS OF WATER DEPLETION ON YIELD AND QUALITY OF COTTON FOR THE SURFACE-IRRIGATED PLOTS (1974)

Depletion (%)	Yield kg/ha	Lint %	2.5% span	Unif. ratio	MIC	Strength	Elongation
			1st harvest				
25	836^{ab}	37.6	1.17	46.8	3.6^{a}	21.5	6.1
50	890^{a}	37.1	1.18	47.0	3.9^{ab}	22.0	6.2
75	801^{b}	37.5	1.19	47.0	4.1^{b}	21.9	6.3
			2nd harvest				
25	168	38.8	1.17^{a}	46.8	3.7	21.2	6.7
50	207	38.1	1.17^{a}	45.8	3.6	21.2	6.8
75	185	38.2	1.20^{b}	46.3	3.8	21.7	6.6
			1st and 2nd harvests combined				
25	1000^{a}	38.2	1.17	46.0	3.7	21.4	6.4
50	1100^{b}	37.6	1.17	46.6	3.8	21.6	6.5
75	986^{a}	37.8	1.19	46.7	4.0	21.8	6.4

Means followed by common letter are not significantly different at the 5% or less level of probability.

in 1973. In 1973 the highest micronaire occurred at 25 percent depletion and in 1972 the highest micronaire occurred at 50 percent depletion.

Yield and Quality for the Combined Years 1972, 1973 and 1974 - The individual plot yields are presented in Appendix Table 24. An analysis of variance for cotton yield is presented in Table 40 for the surface-irrigated plots.

Table 40. ANALYSIS OF VARIANCE FOR COTTON YIELD FOR THE SURFACE-IRRIGATED PLOTS FOR THE COMBINED YEARS 1972, 1973 AND 1974

Source of variation	Degrees of freedom	F value
Replication	2	---
Years	2	104.00^{b}
Error A	4	---
Harvest date	1	459,500.00^{b}
Error B	2	---
Year X harvest date	2	74.17^{b}
Error C	4	---
Efficiency	2	3.14
Depletion	2	3.03
Efficiency X depletion	4	1.42
Error D	16	---
Year X efficiency	4	0.36
Year X depletion	4	1.45
Year X efficiency X depletion	8	0.88
Error E	32	---
Harvest date X efficiency	2	0.21
Harvest date X depletion	2	1.41
Harvest date X efficiency X depletion	4	0.58
Error F	16	---
Year X harvest X efficiency	8	0.74
Year X harvest X depletion	8	0.38
Year X harvest X depletion X efficiency	8	0.42
Error G	32	---
Total	161	

Coefficient of variation = 18.3% mean = 1090 kg/ha

[a,b] Significant at the 5 and 1% level of probability, respectively.

Yield varied significantly between years and harvests. The yield differences resulting from years were due to natural variation in weather patterns, seeding dates, disease and insect infestations. The yield differences due to harvest date were of little importance since the harvest date is established by the availability of field labor and not soil-water management. The efficiency and depletion treatments, while significant at the 10 percent level, were not significantly different at the 5 percent level of probability. The average yields per treatment for 1972, 1973 and 1974, and for these years combined, are presented in Table 41. The general trends due to the effects of efficiency and depletion on yield are presented also, in Figure 12.

Table 41. EFFECTS OF IRRIGATION EFFICIENCY AND WATER DEPLETION TREATMENTS ON THE TOTAL YIELDS OF COTTON FOR THE SURFACE-IRRIGATED PLOTS. YIELDS IN kg/ha

Water depletion %	Irrigation efficiency (%) 80	90	100	Average
		1972		
25	930	752	803	828
50	842	961	1000	935
75	1070	976	888	977
Average	946	896	897	913
		1973		
25	1490	1270	1180	1310
50	1390	1410	1390	1390
75	1340	1280	1300	1310
Average	1400	1320	1290	1340
		1974		
25	1050	1020	930	1000
50	1140	1130	1030	1100
75	1080	941	930	984
Average	1090	1030	963	1030
		1972, 1973 and 1974 (combined)		
25	1160	1010	969	1050
50	1120	1170	1140	1140
75	1160	1070	1040	1090
Average	1150	1080	1050	1090

In general, the 50 percent depletion treatment yielded more than the 25 percent and 75 percent depletion treatments at the 90 percent and 100 percent levels of efficiency. As can be seen in Figure 12, yields tended to decrease with increasing efficiency with the exception of the 50 percent depletion treatments. Although variations in yield could not be statistically attributed to the treatments applied, these general trends persisted throughout the three-year study. The coefficient of variation averaged 18.3 percent for the three years. This indicates that with the three replication design employed, the smallest difference that could be detected would, on the average, be about 200-220 kg/ha, whereas the difference between the 100 percent and 80 percent efficiency treatments averaged 129 kg/ha. In order to detect a 110 kg/ha difference, at least 14 replications would be required.

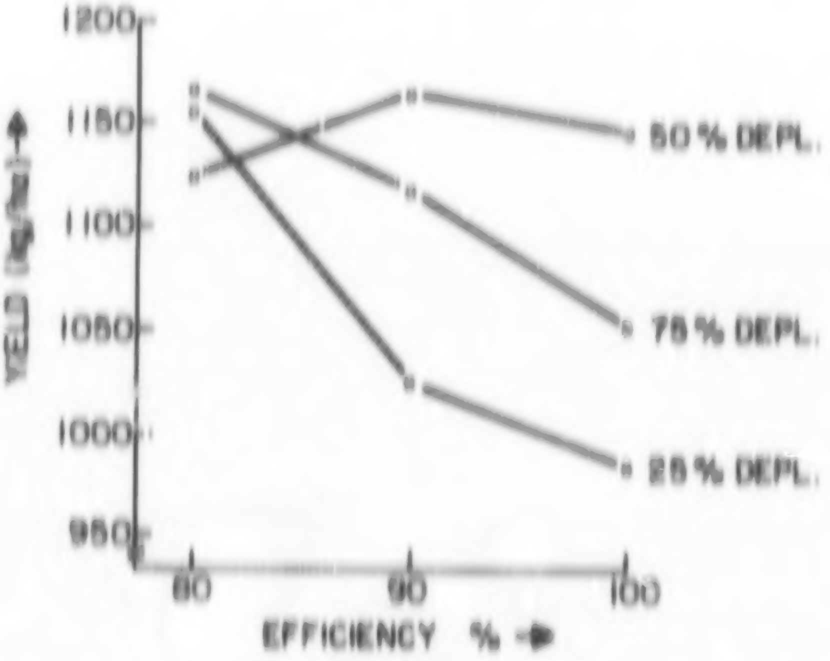

Figure 12. General trends in the total yield of cotton due to depletion and and efficiency (averages of 1972, 1973 and 1974). Parameters shown are percent depletion.

The cotton quality data from the individual plot harvests are presented in Appendix Tables 25-30. A summary of the analysis of variance for these data is presented in Table 42.

Table 42. PARTIAL ANALYSIS OF VARIANCE FOR COTTON QUALITY FACTORS FOR THE COMBINED YEARS 1972, 1973 AND 1974 (SURFACE-IRRIGATED PLOTS)

Source of variation	Lint %	2.5% span	Unif. ratio	MIC	Strength	Elongation
Years	b	b	b	ns	b	b
Harvest date	a	ns	b	b	b	ns
Efficiency	ns	ns	a	ns	ns	ns
Depletion	ns	ns	b	a	ns	ns
Efficiency x depletion	ns	ns	ns	a	ns	b
Year x efficiency	ns	ns	a	ns	ns	ns
Year x depletion	ns	ns	ns	ns	ns	ns
Year x depletion x efficiency	ns	ns	ns	ns	a	ns

a,b denote significant differences at the 5 percent and 1 percent levels of probability, respectively.

ns denotes no significant difference.

Between years, significant differences were found for lint percent, 2.5% span, uniformity ratio, strength and elongation (See Glossary.) Of these, only the uniformity ratio was significantly affected by the treatments applied. This implies that the lint percent, 2.5% span, strength and elongation are influenced more by fluctuations in seasonal weather patterns than by irrigation management.

The two quality factors, lint percent and 2.5% span, primarily determine the value of the cotton crop. (Although, if MIC is less than 3.0, the cotton is discounted.) The significant interaction shown for strength is difficult to interpret since neither efficiency nor depletion affected this factor directly. This is the only significant third order interaction present. It indicates that fiber strength depends, in a complicated fashion, on weather conditions and soil moisture history.

The uniformity ratio was affected by both efficiency and depletion treatments.

Since the year x depletion interaction is nonsignificant, the effect of depletion was similar in all years and the highest uniformity ratio was produced at 25 percent depletion each year.

While the quality data are interesting, most are of minor importance since the economic value of the crop is determined primarily by yield, lint percent, and 2.5% span.

TRICKLE IRRIGATION

Effects on Water Use and Deep Percolation

The amounts of irrigation and rain water received by the trickle plots during 1972, 1973 and 1974 are presented in Table 43.

Table 43. AMOUNTS OF IRRIGATION AND RAIN WATER ON TRICKLE PLOTS, AND CALCULATED EVAPOTRANSPIRATION (ISS) (1972 THROUGH 1974)

Treatment	Total water applied[a] Irrigation (cm)	Rain (cm)	Total (cm)	Computed[b] (cm)
		1972		
0.2 bar	38.6	26.7	65.3	55.1
0.8 bar	13.8	26.7	40.5	55.1
		1973		
0.2 bar	35.2	20.6	55.8	54.9
0.8 bar	32.2	20.6	52.8	54.9
		1974		
0.2 bar	35.7	25.1	60.8	58.7
0.8 bar	26.2	25.1	51.3	58.7

[a] From stand establishment to harvest (October 31)

[b] Computed from pan in 1972 and by ISS in 1973 and 1974 (Table 11).

Comparing the data in Table 43 with those in Tables 8, 9 and 10, it is clear that during each project year the amounts of water used on the trickle plots were smaller than those used on the surface-irrigated plots, including the 100 percent efficiency surface treatment. In 1973, the average amount of water applied to the 100 percent efficiency surface treatment was 67.1 cm versus

54.3 cm, or 20 percent less water, to the trickle plots. In 1974, these amounts were 77.5 cm versus 56.0 cm, or 28 percent less irrigation water on the trickle plots than on the surface-irrigated plots.

Comparing the amounts of water applied to the trickle plots (Table 43) with the average water use as calculated with ISS for the surface-irrigated plots, it appears that in 1973 and 1974 the correct amounts of water were used on the 0.2 bar trickle treatment. The amounts of water applied to the 0.6 bar trickle plots were less than water use as calculated with ISS.

The total amount of water use as predicted with ISS was fairly close to that determined with tensiometers in the trickle-irrigated plots providing added confidence to the use of ISS for scheduling irrigations.

Effects on Soil Salinity

Concentration of Saturation Extracts - The results of the analyses of the saturation extracts of soil samples from the trickle-irrigated plots are presented in Appendix Tables 1-6. The same results, expressed in g of salt per 100 g of dry soil are presented in Tables 44-48.

Table 44. SALT CONTENT OF SOIL (g/100g OF SOIL) IN TRICKLE-IRRIGATED PLOTS (DECEMBER 1972)

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1, row	0.17	0.14	0.05	0.04	0.05	0.05	0.03	0.03
T1, center	0.18	0.12	0.04	0.06	0.05	0.03	0.02	0.02
T2, row	0.17	0.14	0.10	0.12	0.14	0.09	0.04	0.03
T2, center	0.16	0.12	0.09	0.06	0.06	0.06	0.02	0.05
T3, row	0.07	0.09	0.09	0.09	0.07	0.08	0.08	0.03
T3, center	0.27	0.17	0.10	0.08	0.10	0.08	0.06	0.02
T4, row	0.08	0.11	0.15	0.21	0.09	0.09	0.05	0.03
T4, center	0.15	0.18	0.18	0.20	0.12	0.12	0.06	0.02
T5, row	0.11	0.23	0.11	0.12	0.16	0.15	0.08	0.05
T5, center	0.15	0.17	0.08	0.11	0.11	0.09	0.06	0.04
T6, row	0.15	0.15	0.19	0.09	0.12	0.10	0.07	0.04
T6, center	0.15	0.14	0.19	0.07	0.09	0.09	0.05	0.04
Mean	0.15	0.14	0.11	0.10	0.098	0.085	0.051	0.033
St. Dev.	0.056	0.038	0.052	[illegible]	0.035	0.031	0.019	0.010
Mean, row	0.12	0.14	0.12	0.11	0.11	0.092	0.056	0.036
Mean, center	0.18	0.14	0.11	0.097	0.089	0.078	0.046	0.031

Table 45. SALT CONTENT OF SOIL (g/100g OF SOIL) IN TRICKLE-IRRIGATED PLOTS (MAY 1973)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1, row	0.08	0.07	0.08	0.08	0.08	0.11	0.05	0.07
T1, center	0.09	0.13	0.09	0.10	0.12	0.09	0.05	0.05
T2, row	0.06	0.08	0.12	0.05	0.09	0.12	0.06	0.07
T2, center	0.15	0.12	0.07	0.07	0.11	0.14	0.06	0.08
T3, row	0.09	0.10	0.15	0.05	0.06	0.12	0.10	0.06
T3, center	0.19	0.17	0.16	0.10	0.09	0.10	0.08	0.07
T4, row	0.07	0.09	0.12	0.21	0.15	0.18	0.10	0.04
T4, center	0.16	0.11	0.15	0.15	0.13	0.14	0.08	0.04
T5, row	0.10	0.09	0.10	0.07	0.11	0.19	0.12	0.07
T5, center	0.22	0.14	0.11	0.08	0.09	0.15	0.09	0.07
T6, row	0.08	0.07	0.07	0.06	0.09	0.11	0.02	0.06
T6, center	0.13	0.14	0.12	0.06	0.12	0.14	0.09	0.07
Mean	0.12	0.11	0.11	0.092	0.10	0.13	0.081	0.063
Std. Dev.	0.052	0.031	0.031	0.051	0.025	0.021	0.024	0.014
Mean, row	0.080	0.085	0.11	0.088	0.098	0.14	0.087	0.064
Mean, center	0.16	0.14	0.12	0.095	0.11	0.13	0.076	0.062

Table 46. SALT CONTENT OF SOIL (g/100g OF SOIL) IN TRICKLE-IRRIGATED PLOTS (DECEMBER 1973)

Plot No.	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1, row	0.14	0.11	0.08	0.16	0.12	0.10	0.09	0.04
T1, center	0.12	0.13	0.14	0.16	0.19	0.15	0.04	0.05
T2, row	0.11	0.12	0.08	0.11	0.11	0.08	0.04	0.01
T2, center	0.03	0.05	0.06	0.11	0.09	0.12	0.05	0.01
T3, row	0.08	0.10	0.05	0.07	0.09	0.08	0.03	0.04
T3, center	0.12	0.13	0.08	0.08	0.12	0.08	0.02	0.05
T4, row	0.09	0.13	0.12	0.14	0.10	0.18	0.03	0.02
T4, center	0.13	0.15	0.17	0.16	0.08	0.13	0.07	0.04
T5, row	0.07	0.09	0.07	0.11	0.14	0.07	0.05	0.02
T5, center	0.09	0.11	0.11	0.12	0.09	0.06	0.05	0.02
T6, row	0.11	0.15	0.28	0.14	0.23	0.24	0.13	0.08
T6, center	0.09	0.12	0.15	0.09	0.30	0.25	0.21	0.12
Mean	0.099	0.12	0.12	0.12	0.14	0.13	0.067	0.042
Std. Dev.	0.030	0.026	0.064	0.034	0.066	0.064	0.054	0.033
Mean, row	0.099	0.12	0.11	0.12	0.13	0.12	0.062	0.036
Mean, center	0.099	0.12	0.12	0.12	0.14	0.13	0.073	0.049

Table 47. SALT CONTENT OF SOIL (g/100g OF SOIL) IN TRICKLE-IRRIGATED PLOTS (DECEMBER 1974)

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1, row	0.07	0.09	0.11	0.13	0.23	0.09	0.14	0.06
T1, center	0.11	0.14	0.20	0.27	0.21	0.17	0.10	0.05
T2, row	0.08	0.12	0.17	0.13	0.19	0.17	0.18	0.06
T2, center	0.14	0.17	0.15	0.07	0.14	0.17	0.12	0.04
T3, row	0.07	0.08	0.07	0.08	0.10	0.13	0.07	0.03
T3, center	0.06	0.15	0.09	0.08	0.11	0.15	0.06	0.05
T4, row	0.09	0.06	0.08	0.14	0.18	0.18	0.18	0.06
T4, center	0.19	0.24	0.28	0.19	0.20	0.17	0.12	0.03
T5, row	0.05	0.06	0.05	0.08	0.13	0.16	0.10	0.07
T5, center	0.10	0.17	0.13	0.12	0.17	0.18	0.11	0.09
T6, row	0.08	0.12	0.19	0.28	0.20	0.30	0.33	0.21
T6, center	0.14	0.10	0.34	0.22	0.29	0.30	0.34	0.21
Mean	0.098	0.13	0.15	0.15	0.18	0.19	0.15	0.079
Std. Dev.	0.042	0.055	0.088	0.074	0.054	0.055	0.091	0.061
Mean, row	0.069	0.088	0.11	0.14	0.17	0.19	0.17	0.080
Mean, center	0.12	0.18	0.20	0.16	0.19	0.19	0.14	0.077

Table 48. SALT CONTENT OF SOIL (g/100 g OF SOIL) OUTSIDE TRICKLE-IRRIGATED PLOTS (DECEMBER 1974)

	Depth (cm)							
Plot No.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
T1W[a]	0.04	0.10	0.13	0.09	0.09	0.06	0.06	-
T2W	0.05	0.16	0.12	0.08	0.06	0.07	0.07	0.05
T3W	0.08	0.16	0.17	0.06	0.06	0.11	0.12	0.07
T1E[b]	0.09	0.10	0.08	0.05	0.10	0.06	0.09	0.04
T2E	0.04	0.06	0.11	0.07	0.11	0.07	0.07	0.04
T3E	0.10	0.14	0.12	0.07	0.10	0.12	0.08	0.03
T4E	0.03	0.08	0.08	0.11	0.08	0.11	0.07	0.03
T5E	0.12	0.14	0.14	0.09	0.10	0.08	0.05	0.06
T6E	0.16	0.19	0.31	0.14	0.18	0.26	0.21	0.18
Mean	0.077	0.12	0.14	0.089	0.098	0.11	0.091	0.063
Std. Dev.	0.043	0.045	0.067	0.022	0.037	0.062	0.049	0.049

[a] W designates west of plot.

[b] E designates east of plot.

The trickle-irrigated plots were sampled for soil salinity differently than were the surface-irrigated plots. Samples were taken immediately on the trickle lines and also at the mid-point between trickle lines.

The analysis of variance for the trickle plot salinity data for fall 1972, 1973 and 1974 is presented in Table 49. Because of the effect of location, the analysis of variance is somewhat more complicated than that shown in Table 20 for the surface-irrigated plots. Also in comparing the two tables, the coefficients of variation associated with the error terms B are dissimilar. This indicates that the natural variation in salinity by depth was less in the trickle-irrigated plots than in the surface-irrigated plots.

Table 49 implies that not only did salinity levels vary significantly between years and between depths, but the significant year x depth interaction indicates that soil salts were distributed differently by depth in different years. Of more interest is the interaction of year x depth x location (location refers to samples taken between or on trickle lines). This three-way interaction is depicted in Figure 13 where salt distribution by depth is compared graphically during each year for the two locations.

These illustrations show that the 120-mm preharvest rain in 1973 moved considerable quantities of salts from shallow depths deep into the profile. This is reflected in the increase in salinity in the subsoil and the decrease in salinity near the surface. Late season rains in 1973 and 1974 also contributed to the downward movement of salts in the profile. Surface salinity would have been much higher between the rows if it were not for these rains since salt crusts were observed on the soil surface prior to the rains.

The nonsignificant year x treatment interaction indicates that soil salts accumulated (or leached) at almost the same rate under the wet and dry trickle treatments. However, the significant location x treatment and depth x location x treatment interactions imply that the soil salinity profiles were modified depending on the soil-water treatment and distance from the trickle lines. These interactions are shown in Figure 14 where the soil salinity differences - between row minus below row ("below row" also

Table 49. ANALYSIS OF VARIANCE FOR SOIL SALINITY BASED ON SATURATION EXTRACTS FROM THE TRICKLE-IRRIGATED PLOTS (FALL SAMPLES 1972, 1973 AND 1974)

Source of variation	Degrees of freedom	F value
Replication	2	-
Years (Y)	2	8.45 a
Error A	4	c.v. = 70.2%
Depths (D)	7	10.26 b
Error B	14	c.v. = 48.2%
Location (L)	1	3.69 ns
Error C	2	c.v. = 66.9%
Treatment (T)	1	0.50 ns
Error D	2	c.v. = 232%
Y X D	14	8.08 b
Error E	28	c.v. = 30.0%
Y X L	2	10.53 b
Error F	4	c.v. = 20.9%
Y X T	2	4.84 ns
Error G	4	c.v. = 71.4%
D X T	7	0.94 ns
Error H	14	c.v. = 55.7%
D X L	7	2.14 ns
Error I	14	c.v. = 31.2%
L X T	1	36.51 a
Error J	2	c.v. = 12.4%
Y X D X L	14	3.16 b
Error K	28	c.v. = 23.4%
Y X D X T	14	1.45 ns
Error L	28	c.v. = 35.1%
D X L X T	7	2.79 a
Error M	14	c.v. = 19.4%
Y X L X T	2	0.10 ns
Error N	4	c.v. = 47.1%
Y X D X L X T	14	1.10 ns
Error O	28	c.v. = 26.2%

a,b denote significance at the 5% and 1% level of probability, respectively, ns denotes no significant difference.

designated "on row") - are graphically displayed. These results indicate that, at depths of less than 70 cm, in the 0.2 bar treatment more salts were found between the rows than on the rows, whereas in the 0.6 bar treatment the salts were distributed fairly uniformly. The data in Figures 13 and 14 are also given in Tables 50 and 51.

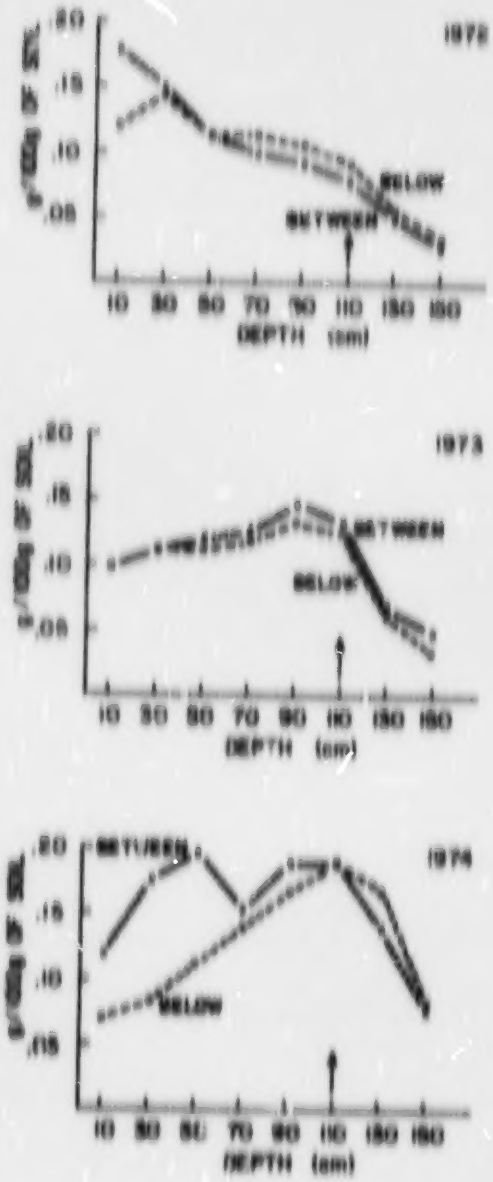

Figure 13. Comparison of salt contents of soil samples taken on (below) trickle lines (dashed lines) and between trickle lines (solid lines). The three graphs shown are for post harvest samples taken in 1972, 1973 and 1974. Vertical arrow denotes average depth to sand for the trickle treatments.

The results also indicate that some of the percolating salts can accumulate in the sands underlying the experimental site. Since the rooting depth of cotton appears to be restricted to the soil profile above the sand, probably as a result of the sharp interface between the clay loam and the underlying sand, any salt accumulation in the sands would not be detrimental to cotton production.

Table 30. SOIL SALINITY (g/100g OF SOIL) FOR SAMPLING LOCATIONS BELOW AND BETWEEN TRICKLE LINES AS A FUNCTION OF DEPTH

Location	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
					1972			
Below	0.12	0.16	0.11	0.11	0.11	0.09	0.06	0.03
Between	0.18	0.14	0.11	0.10	0.09	0.08	0.04	0.03
					1973			
Below	0.10	0.12	0.11	0.12	0.13	0.13	0.06	0.04
Between	0.10	0.11	0.12	0.12	0.14	0.13	0.07	0.05
					1974			
Below	0.07	0.08	0.11	0.13	0.17	0.19	0.17	0.08
Between	0.12	0.07	0.20	0.15	0.19	0.19	0.14	0.08
			Averages of 1972, 1973 and 1974					
Below	0.10	0.11	0.11	0.12	0.14	0.13	0.09	0.05
Between	0.13	0.14	0.14	0.13	0.14	0.13	0.09	0.05

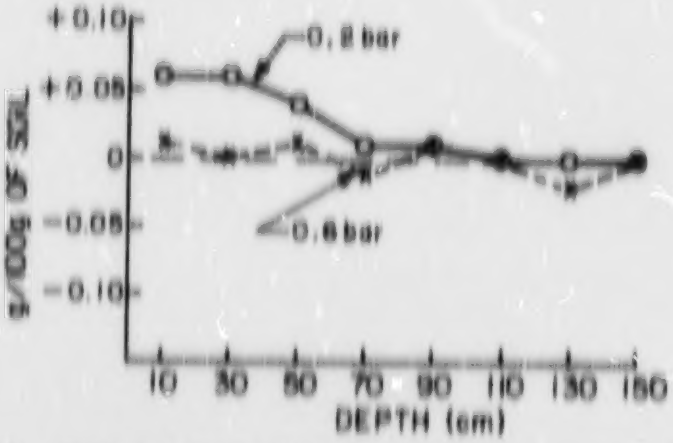

Figure 14. Soil salinity differences due to sampling location (between row minus below row) for the 0.2 and 0.6 bar trickle treatments. The differences are for the means of the 1972, 1973 and 1974 post harvest samples.

Table 51. SOIL SALINITY (g/100g OF SOIL) FOR SAMPLING LOCATIONS BELOW AND BETWEEN TRICKLE LINES AS A FUNCTION OF DEPTH AND SALINITY DIFFERENCES BETWEEN LOCATIONS (BETWEEN ROW MINUS BELOW ROW). MEANS OF 1972, 1973 AND 1974 POST HARVEST SAMPLES.

Location	Depth (cm) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
				0.2 BAR TREATMENT				
Between	0.14	0.16	0.13	0.13	0.12	0.12	0.07	0.04
Below	0.08	0.10	0.09	0.12	0.11	0.12	0.07	0.04
Difference	0.06	0.06	0.04	0.01	0.01	0.00	0.00	0.00
				0.6 BAR TREATMENT				
Between	0.13	0.13	0.15	0.12	0.16	0.15	0.10	0.06
Below	0.12	0.13	0.14	0.13	0.15	0.15	0.12	0.06
Difference	0.01	0.00	0.01	-0.01	0.01	0.00	-0.02	0.00

Composition of Saturation Extracts - The saturation extracts of the soil samples taken from the trickle-irrigated plots in the spring of 1973 were analyzed for chemical composition (See Appendix Tables 7-14). The results of these analyses are summarized in Tables 52, 53 and 54. Table 52 presents the mean composition of saturation extracts of samples taken from below the trickle lines (May, 1973). Table 53 presents the mean composition of the samples from in between the trickle lines and Table 54 combines the data from Tables 52 and 53.

Table 52. MEAN COMPOSITION OF SATURATION EXTRACTS (meq/l) OF SAMPLES TAKEN FROM BELOW THE TRICKLE LINES (MAY 1973) AS A FUNCTION OF DEPTH

Depth (cm)	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	1.3	18.3	6.3	2.1	9.2	0.7	1.8	0	8.3	6.1	0.7
20-40	1.5	20.3	7.5	2.5	9.6	0.7	2.3	0	8.3	8.5	1.1
40-60	1.8	24.0	8.4	3.2	11.7	0.7	2.7	0	7.3	12.1	1.0
60-80	2.4	34.7	14.8	4.3	14.9	0.7	4.2	0	7.9	19.5	1.4
80-100	2.9	41.9	16.6	5.3	19.3	0.6	6.2	0	6.9	22.6	3.8
100-120	3.8	54.6	24.2	7.2	22.5	0.8	11.6	0	6.5	29.9	2.2
120-140	3.2	44.9	19.5	5.9	18.7	0.8	11.2	0	6.8	22.8	1.6
140-160	2.6	36.7	13.9	4.8	17.3	0.7	8.1	0	6.9	17.7	1.4

Table 53. MEAN COMPOSITION OF SATURATION EXTRACTS (meq/l) OF SAMPLES TAKEN IN BETWEEN THE TRICKLE LINES (MAY 1973) AS A FUNCTION OF DEPTH

Depth (cm)	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	3.5	33.0	13.7	3.8	14.6	0.9	5.8	0	8.3	13.7	2.8
20-40	2.1	29.2	11.9	3.5	12.9	1.0	4.4	0	8.4	12.2	3.4
40-60	2.1	28.9	11.6	3.7	13.0	0.8	4.5	0	7.2	12.4	2.4
60-80	2.7	36.4	14.7	4.6	16.3	0.8	6.8	0	6.5	17.0	3.6
80-100	3.0	40.5	16.1	4.6	19.1	0.7	7.1	0	7.6	20.1	3.0
100-120	3.4	46.4	20.0	6.0	19.7	0.8	8.9	0	6.6	25.2	3.4
120-140	2.8	39.7	15.7	5.4	17.9	0.8	8.7	0	6.9	19.7	1.6
140-160	2.6	33.7	14.7	4.7	16.1	0.8	7.5	0	6.3	18.5	1.4

Comparing the data in Tables 52 and 53, it may be seen that in the upper 60 cm of soil the concentrations of Ca, Na, Cl, SO_4 and NO_3 were less below (on) the trickle line than in between trickle lines. The lower concentrations of chlorides below the trickle lines indicate considerable leaching around trickle lines and some salt accumulation in between trickle lines. There was no difference in bicarbonate concentration below and in between trickle lines.

Table 54. MEAN COMPOSITION OF SATURATION EXTRACTS (meq/l) OF ALL SAMPLES TAKEN IN THE TRICKLE PLOTS (MAY 1973) AS A FUNCTION OF DEPTH

Depth (cm)	mmhos /cm	Σ Cations	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3
0-20	1.9	25.7	10.0	3.0	11.9	0.8	3.8	0	8.3	9.9	1.8
20-40	1.8	24.8	9.7	3.0	11.3	0.9	3.3	0	8.3	10.1	2.2
40-60	1.9	26.5	9.9	3.5	12.4	0.7	3.6	0	7.3	12.2	1.7
60-80	2.5	35.5	14.8	4.5	15.6	0.7	5.5	0	7.2	18.3	2.5
80-100	2.9	41.2	16.3	5.0	19.2	0.6	6.7	0	7.3	21.2	3.4
100-120	3.6	50.1	21.9	6.5	20.9	0.8	10.1	0	6.5	27.3	2.9
120-140	3.0	42.3	17.6	5.6	18.3	0.8	10.0	0	6.9	21.3	1.6
140-160	2.6	36.5	14.2	4.8	16.8	0.7	7.9	0	6.7	18.0	1.4

Salt Distribution Around Trickle Lines - Salinity sensor readings were made at regular intervals to monitor possible salt accumulation around trickle lines. For each depth in each trickle plot, the data were averaged and plotted versus time (Fig. 15-18). Before August 1, 1973, the number of salinity sensors in each plot were 0 at 5 cm, 5 at 10 cm, 7 at 25 cm and 3 at 40 cm. After August 1, there were 14 sensors at each of these depths (See Materials and Methods). Thus, in constructing Figures 15-18, 5 values were used to compute the average salinity at 10 cm before August 1, and 14 values were used for computing the average values after this date. Rainfall and irrigation data are also presented in Figures 15-18. The data for Plots T5 (Figures 15 and 16) and T2 (Figures 17 and 18) show the same general trends. For both plots, the salinity level responded rather quickly to irrigation or rainfall. For example, preplant irrigations with 20 cm of water during early March 1973 produced a large decrease in soil salinity at all levels in the soil profile. This is shown even more clearly in Figure 19, where the salt distribution in the soil around a trickle line is presented. Pre-irrigation through a trickle line was apparently very effective in moving salt away from the line. Even as far as 45 cm from the trickle line there was a substantial decrease in soil salinity.

An example of leaching by rainfall is shown in Figures 20 and 21. Figure 20 shows the salt distribution around two parallel trickle lines on August 16, 1973. There was clearly some salt accumulation near the soil surface in between trickle lines as a result of irrigation with water which had an electrical conductivity of 1.4 mmhos/cm. However, an unusually large rainstorm of 120 mm effectively moved the salts deep into the profile. There was some runoff from the area, so it is not certain whether the whole 120 mm leached through the profile or only a part of it.

The leachings of the soil profile by irrigation and rainfall (Figures 15-18) were followed by substantial decreases in the salt concentration. The average salt level had a tendency to increase during July and August when irrigation and crop water use were intensive. The fall rains in 1973 and 1974, however, were apparently sufficient to leach out most of the salts accumulated during the previous months.

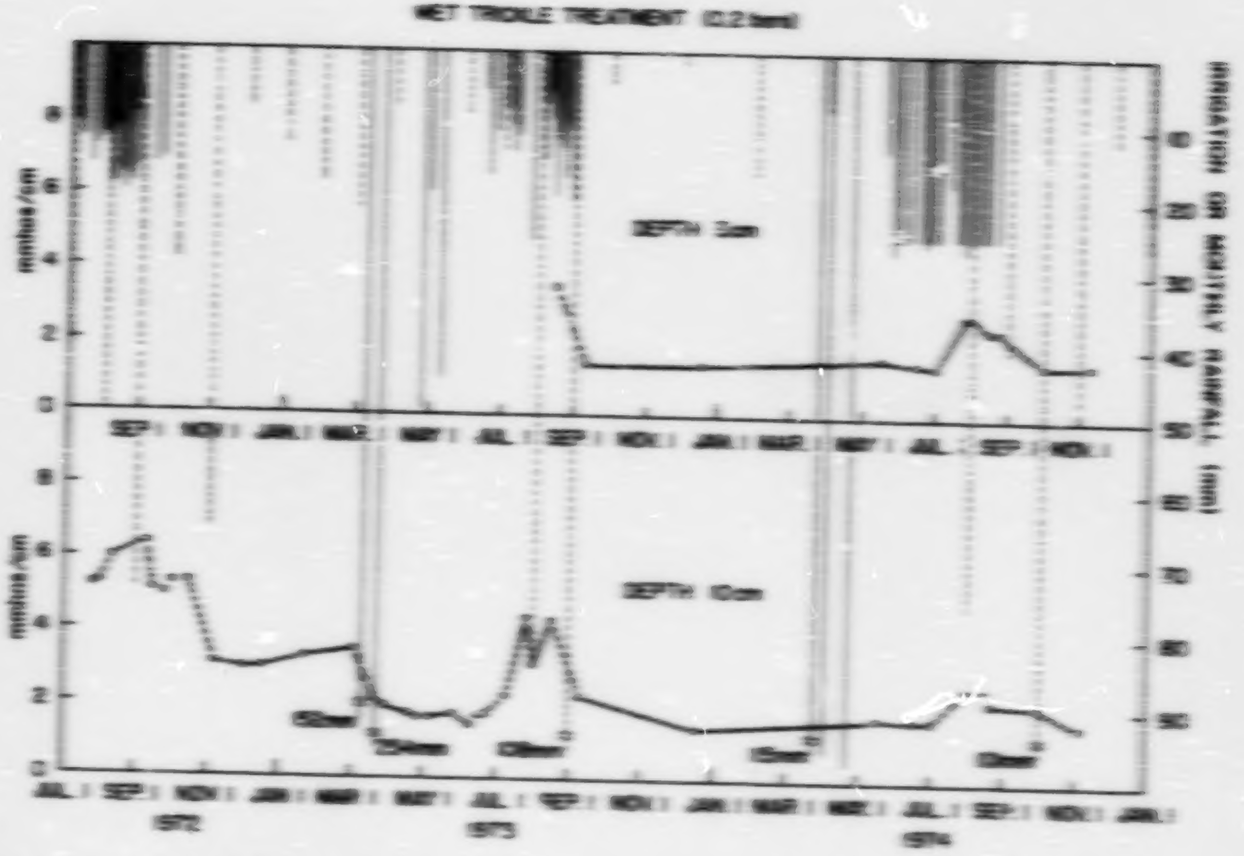

Figure 15. Soil salinity at the 5- and 10-cm depths as estimated by salinity sensors for the 0.2 bar trickle treatment. Vertical dashed lines denote total rainfall for month indicated. Vertical solid lines denote irrigation on date indicated.

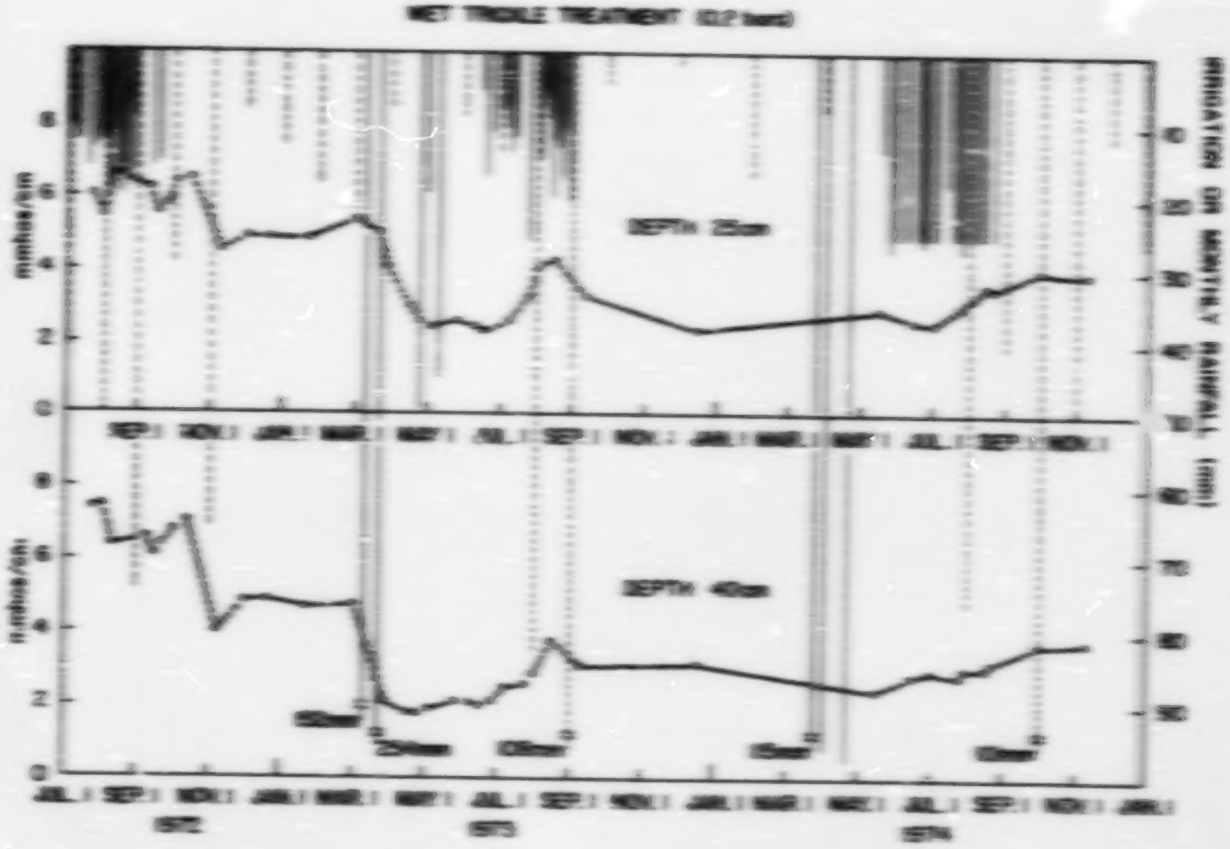

Figure 16. Soil salinity at the 25- and 40-cm depths as estimated by salinity sensors for the 0.2 bar trickle treatment. Vertical dashed lines denote total rainfall for month indicated. Vertical solid lines denote irrigation on date indicated.

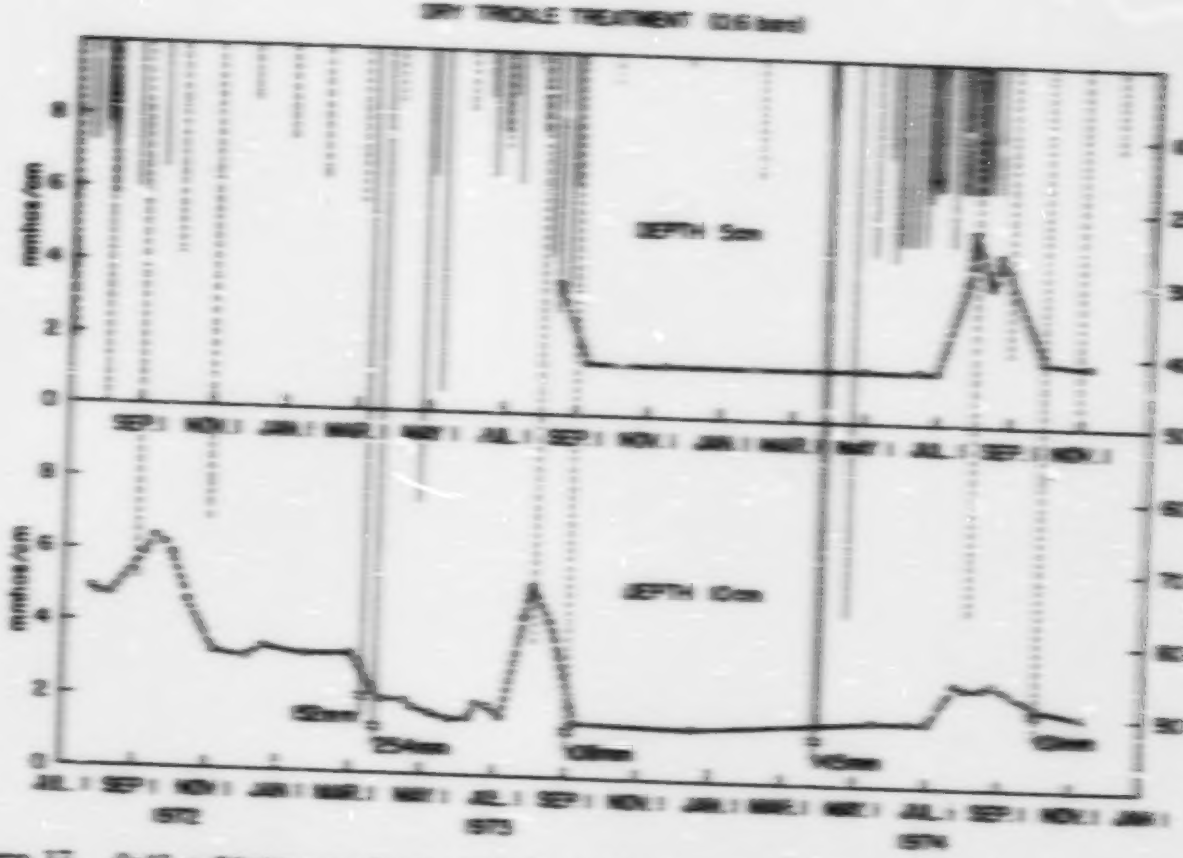

Figure 17. Soil salinity at the 5- and 10-cm depths as estimated by salinity sensors for the 0.6 bar trickle treatment. Vertical dashed lines denote total rainfall for month indicated. Vertical solid lines denote irrigation on date indicated.

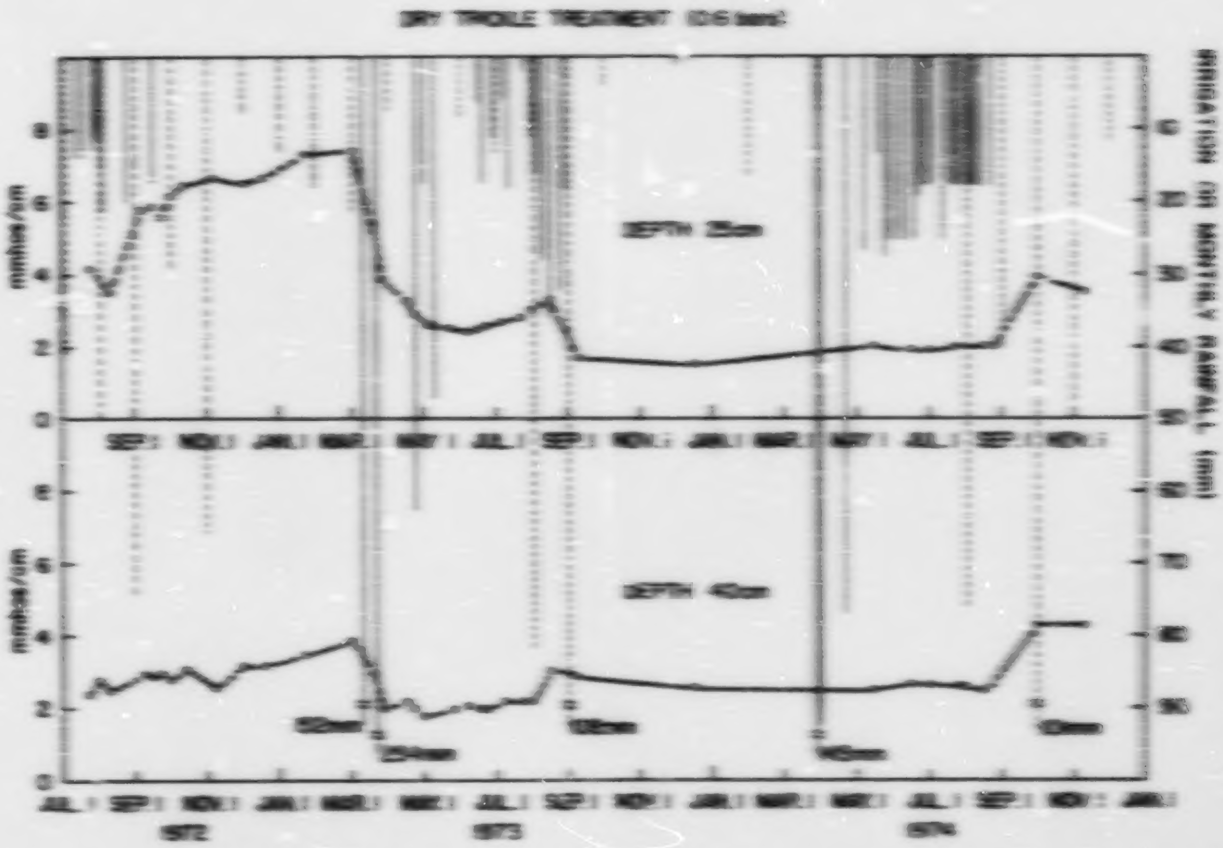

Figure 18. Soil salinity at the 25- and 40-cm depths as estimated by salinity sensors for the 0.6 bar trickle treatment. Vertical dashed lines denote total rainfall for month indicated. Vertical solid lines denote irrigation or date indicated.

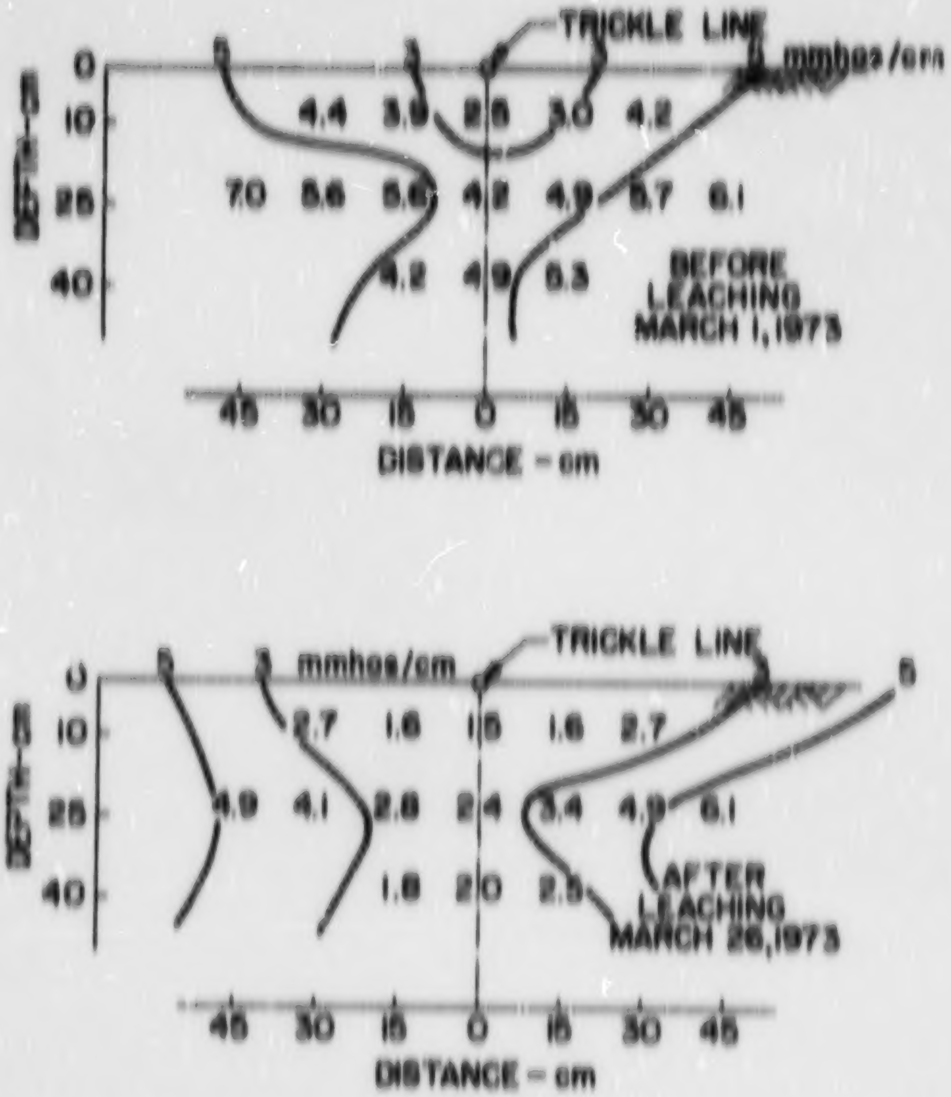

Figure 19. Comparison of soil salinity around a trickle line in plot before (top figure) and after (bottom figure) a 200-mm preirrigation.

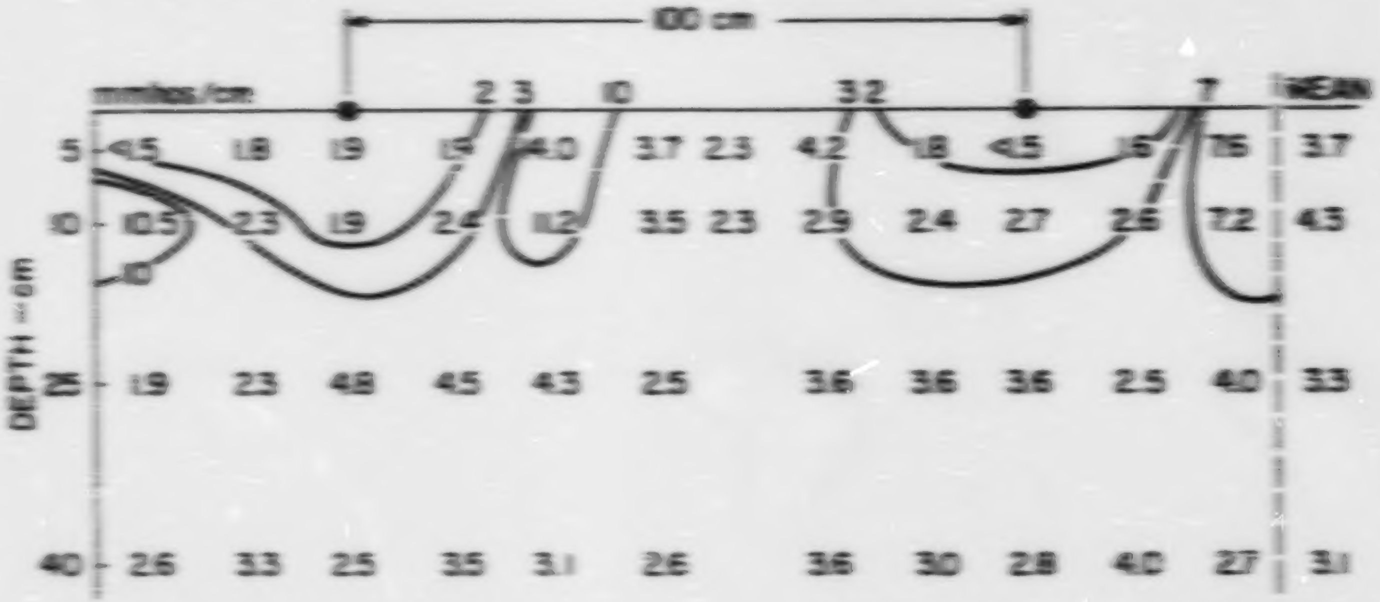

Figure 21. Soil salinity distribution around two parallel trickle lines in plot T2 prior to a [illegible] rain in August 1973.

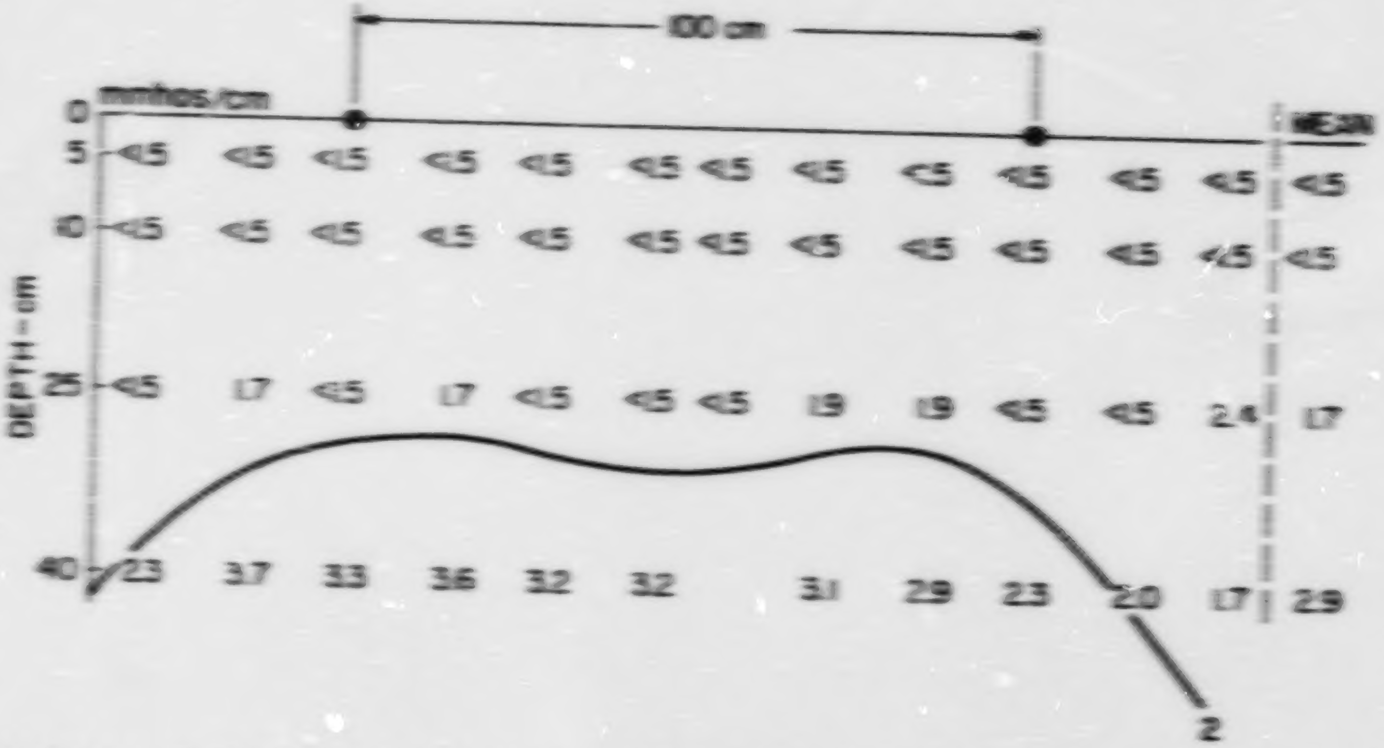

Figure 21. Soil salinity distribution around two parallel trickle lines in plot 32 after a 120-mm rain in August 1971.

It appeared that preirrigation and rain were effective in preventing heavy salt accumulations around trickle lines. This was the case even though all trickle lines were kept at the same location for three successive growing seasons and no tillage (no mixing of soils and salts) was performed.

Effects on Cotton Yields and Quality

Yield and Quality in 1974 - The 1974 cotton yields are presented in Appendix Table 24 and the cotton quality data for the first and second harvests are presented in Appendix Tables 25-30. The average yield and quality data for each of the two trickle treatments are presented in Table 55 for 1974.

Table 55. EFFECTS OF SOIL-WATER TENSION ON YIELD AND QUALITY OF COTTON FROM THE TRICKLE-IRRIGATED PLOTS (1974)

Tension bars	Yield kg/ha	Lint %	2.5% span	Uniformity ratio	MIC	Strength	Elongation
			1st harvest				
.2	969	36.3	1.20	45.7	3.30	20.7	6.30
.6	974	37.1	1.17	46.3	3.27	21.4	6.27
			2nd harvest				
.2	95	39.9	1.16	47.6	3.30	20.3	6.27
.6	99	39.6	1.14	45.0	3.07	20.6	6.43
			1st and 2nd harvests combined				
.2	1060	38.1	1.18	46.6	3.30	20.5	6.28
.6	1070	38.3	1.16	45.6	3.17	21.0	6.35

The treatments applied to the trickle plots had no significant effect during the 1974 season. This is due in part to the heavy infestation of Verticillium wilt that occurred during 1974.

Yield of Cotton for the Combined Years 1972, 1973 and 1974 - The cotton yields from the trickle plots for the years 1972, 1973 and 1974 are presented in Table 56. The analysis of variance for the yield data is presented in Table 57. The analysis of variance showed that treatment had no significant effect on cotton yield.

Table 56. EFFECTS OF SOIL-WATER TENSION ON YIELD (kg/ha) OF COTTON FROM TRICKLE-IRRIGATED PLOTS IN 1972, 1973 AND 1974

Year	Treatment 0.2 bar	 0.6 bar	Mean
1972	1230	1120	1180
1973	1240	1370	1300
1974	1060	1070	1060
Mean	1180	1190	1180

Table 57. ANALYSIS OF VARIANCE FOR COTTON YIELDS FOR THE COMBINED YEARS 1972, 1973 AND 1974 (TRICKLE-IRRIGATED PLOTS)

Source of variation	Degrees of freedom	F value
Replication	2	-
Years (Y)	2	5.71
Error A	4	C.V. = 14.6%
Harvest (H)	1	53.6
Error B	2	C.V. = 40.6%
Y X H	2	7.47
Error C	4	C.V. = 33.2%
Treatment (T)	1	0.001
Error D	2	C.V. = 13.6%
Y X T	2	2.80
Error E	4	C.V. = 11.4%
H X T	1	39.9
Error F	2	C.V. = 16.3%
Y X H X T	2	23.0
Error G	4	C.V. = 13.2%

Comparing the data in Table 36 with those in Table 39 showed that the mean yield from the trickle-irrigated plots was 1180 kg/ha versus 1090 kg/ha from the surface-irrigated plots. Thus, the trickle plots produced on the average 8.3 percent more lint cotton than the surface-irrigated plots and used about 24 percent less irrigation water.

Quantity of Drain Flow - Figures 22, 23, and 24 show drain flow at sampling stations A and B on the Del Rio Drain. During all three years of the study, the early March time period is marked by a sharp increase in flow at both stations. Since preirrigations are initiated at this time of the year, the flow increases could be expected. With the exception of 1972, the increase in drain flow persisted throughout the growing season. A second relative peak in flow rate occurred in July-August, followed by an erratic decline to the winter flow rates.

Figure 25 presents a cumulative frequency distribution for drain flow at sites A and B. Although the Mesilla Drain (estimated length 36 km) enters between the sites, this drain contributes little or nothing to the flow of the Del Rio Drain (estimated length above sites A and B is 42 km).

Figure 25 indicates that during the period December 1971 through 1974, the increase in drain flow between A and B was less than 0.25 m^3/sec, 100 percent of the time, less than 0.11 m^3/sec, 50 percent of the time and less than 0.05 m^3/sec 10-15 percent of the time. These data indicate that at least 50 percent of the time an increase in flow rate of 16 percent or .11 m^3/sec could be expected between the two sites.

A flow rate of .11 m^3/sec is equivalent to 9500 m^3/day. The distance between sites A and B is 4.5 km. Assuming that an area 1 km wide is drained on both sides of the drain, it follows that the downward flux of water in this area would be equivalent to 1 mm/day. These losses were of the same order of magnitude as the drainage losses estimated at the experimental site.

The proximity of the Rio Grande to the Del Rio Drain, however, makes the above interpretation very uncertain. Also, the precise area drained by the Del Rio Drain is unknown, and could easily be much larger or smaller than the 2 x 4.5 km^2 used here.

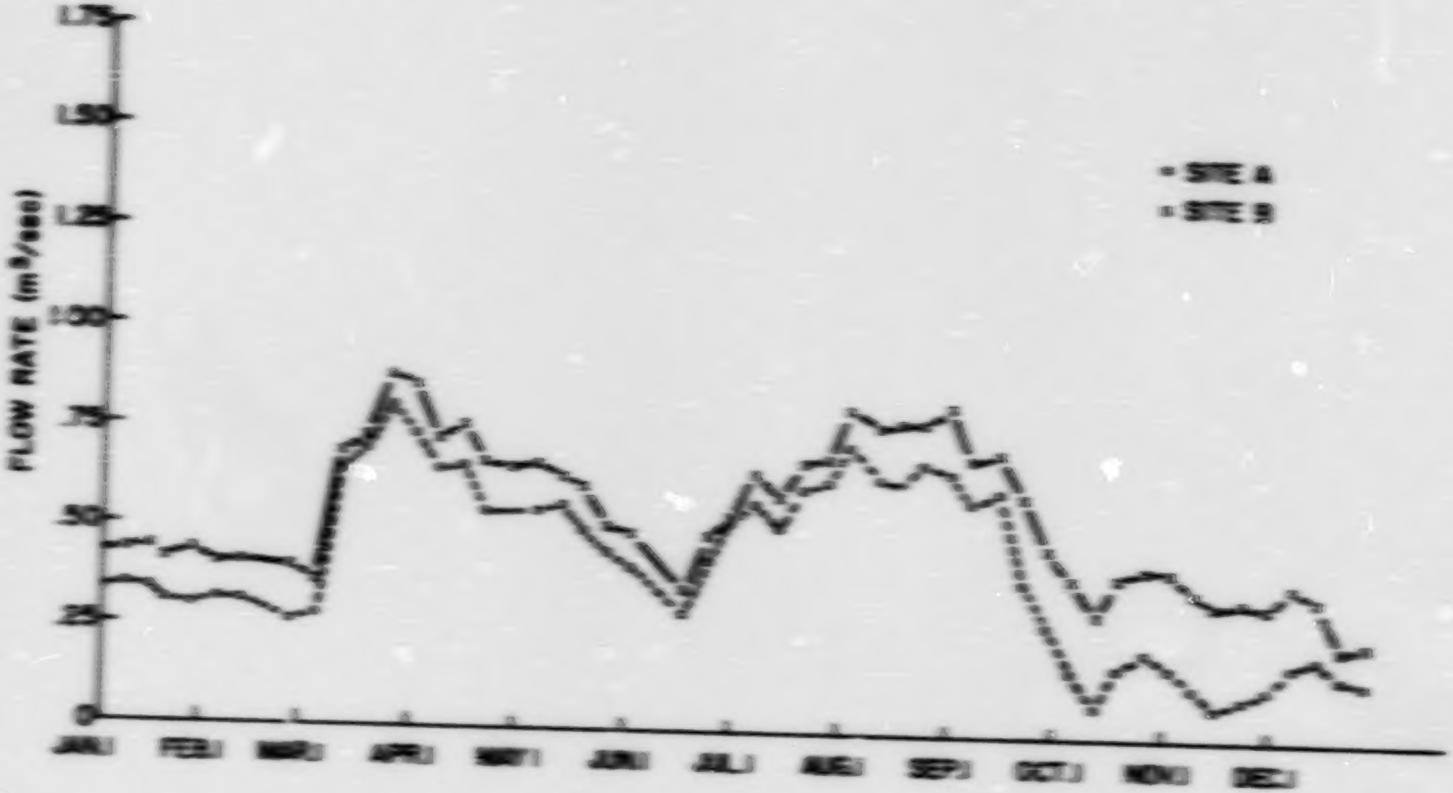

Figure 22. Flow at Del Rio Drain sampling sites A and B in 1972.

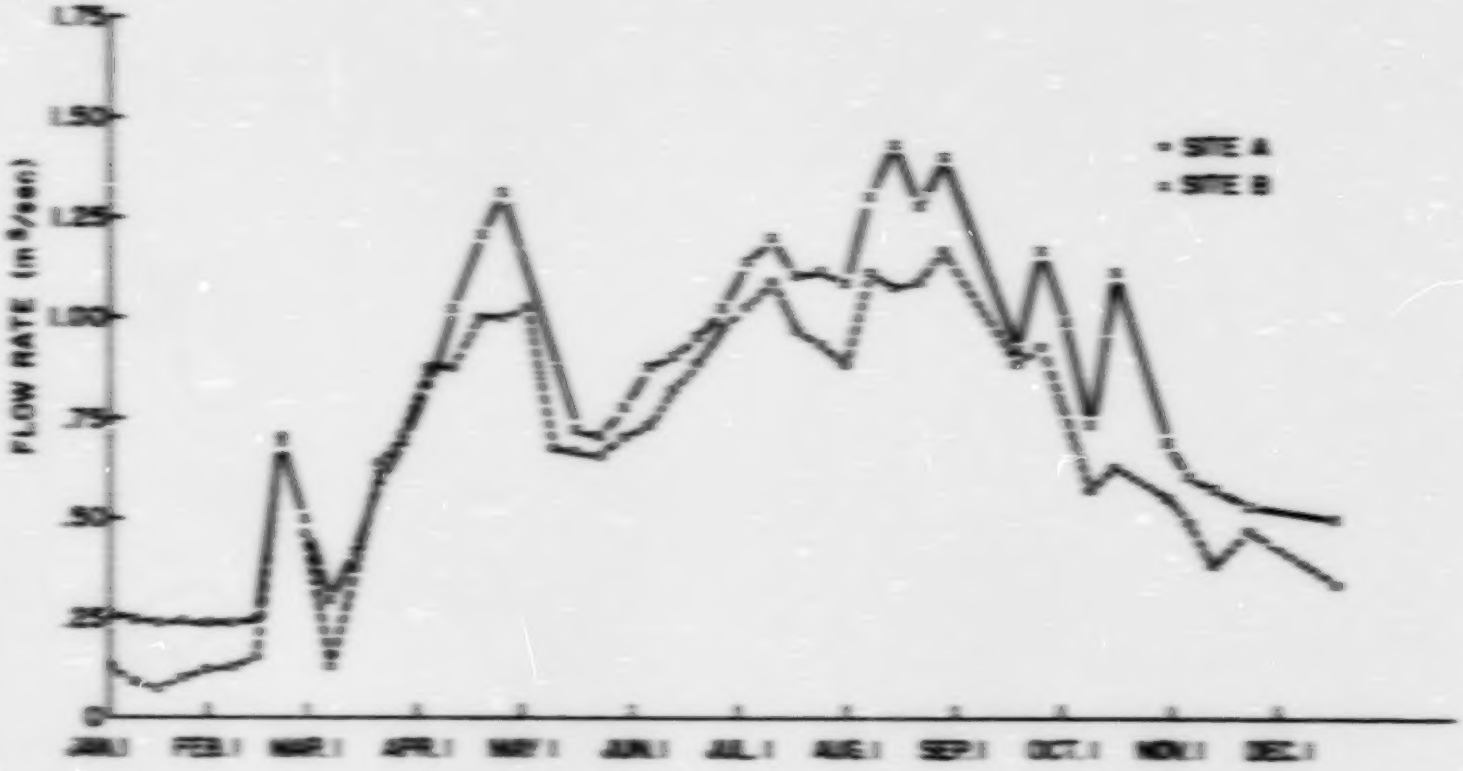

Figure 23. Flow at Del Rio Drain sampling sites A and B in 1973.

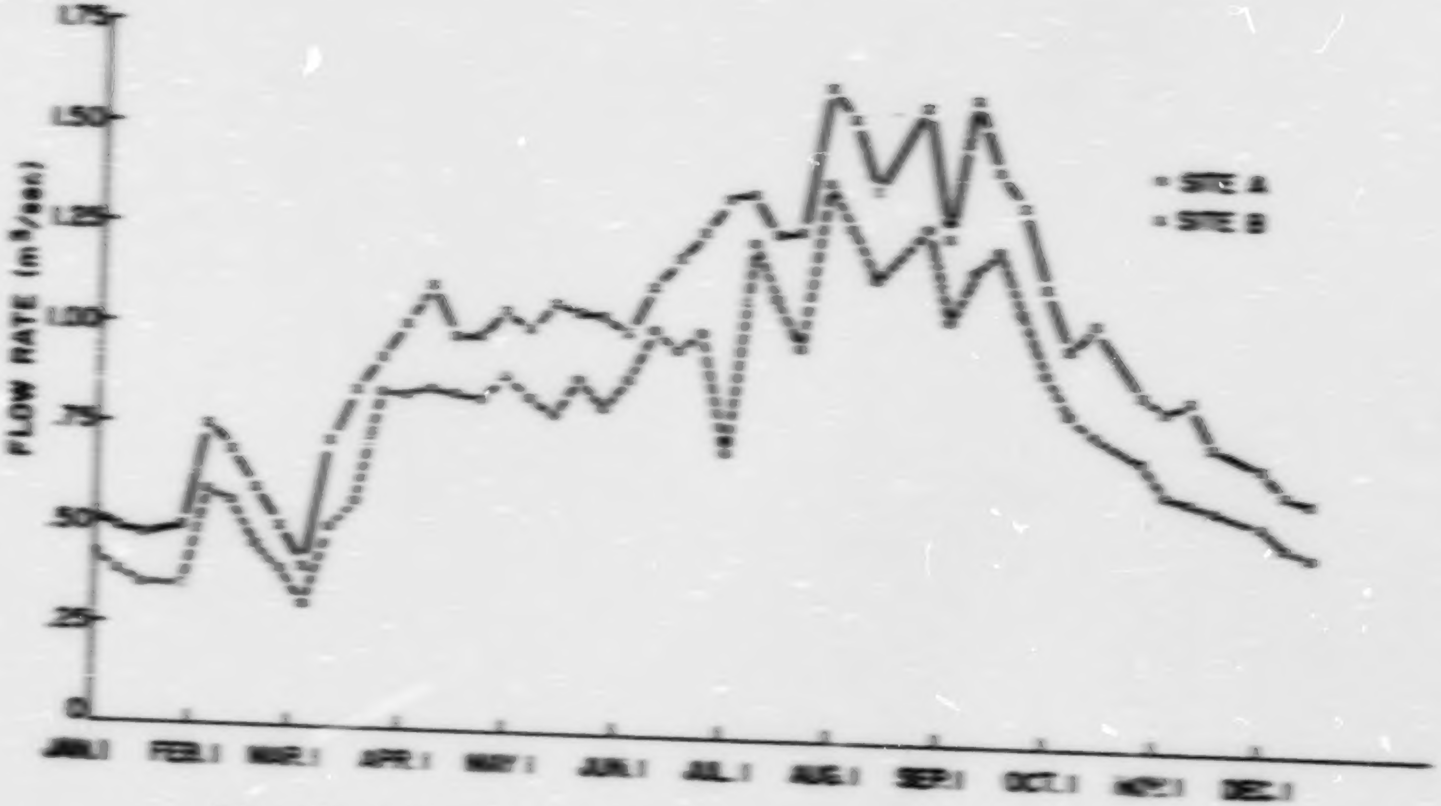

Figure 24. Flow at Del Rio Drain sampling sites A and B in 1974.

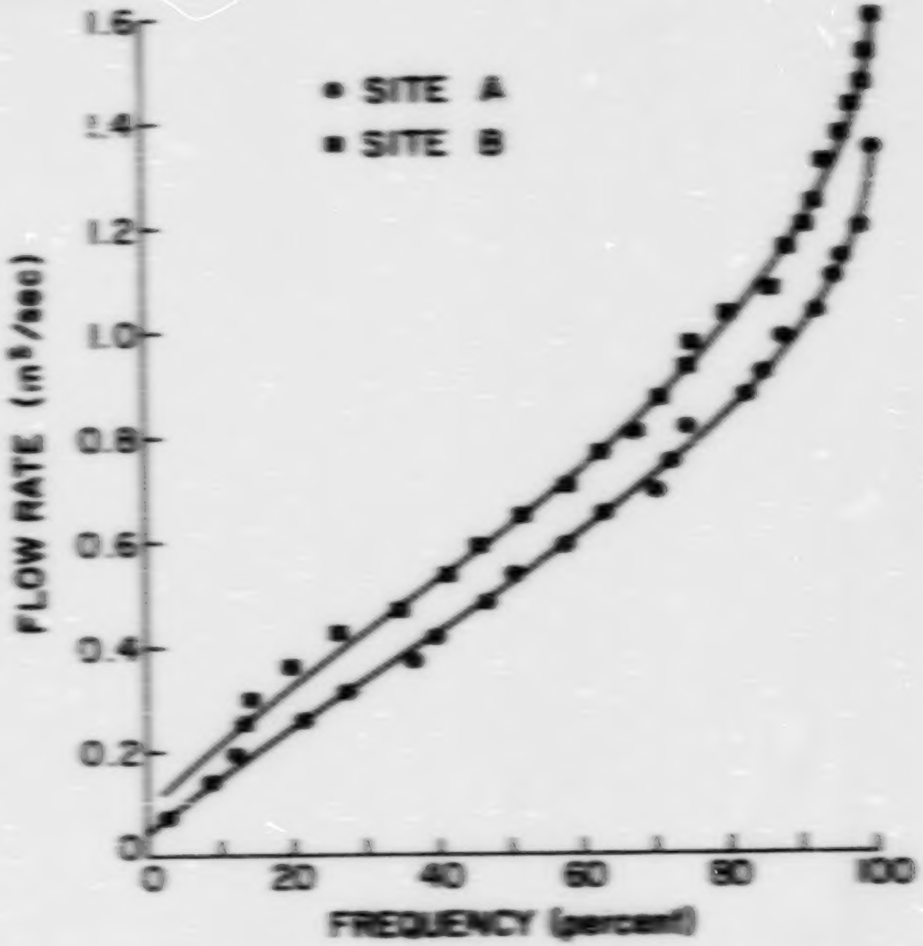

Figure 25. Cumulative frequency distribution of flow rate as measured at [illegible] sites A and B (December 1971 through 1974).

Quality of Drain Flow - Figures 26, 27 and 28 show the electrical conductivities of drainage waters at Del Rio Drain sites A and B. In general, there appeared to be an inverse correlation between drain flow and the electrical conductivities of the water in the Del Rio Drain. When the drain flow increased in early spring, after the start of the irrigation season, the conductivity of the drain water decreased. A decrease in drain flow in the fall, on the other hand, resulted in a gradual increase in salinity of the drain water (Figs. 26 and 27). No further analysis of the correlation between drain flow and drain water quality was made due to lack of groundwater data.

At regular time intervals, the water samples from Del Rio Drain sites A and B were analysed for chemical composition. The results of these analyses are presented in Appendix Tables 31 through 36. Yearly averages of the chemical constituents of the samples from sites A and B are presented in Table 58.

Based on the equivalent weights of the various salts listed in Table 58, the mean salt content at site A during 1972-1974 was 908 ppm. At site B it was 953 ppm, an increase of 45 ppm (equivalent to 10 ppm per km of drain).

The degradation of water quality taking place between sites A and B is further shown in Figure 29.

During the period December 1971 through 1974, the salinity of the drain water always (100 percent of the time) increased at least 3.4 percent (or 0.75 percent/km of drain) between the sites. Figure 29 also indicates that 50 percent of the time salinity could be expected to increase at a rate of 0.86 percent/km of drain.

The results (not shown here) of a frequency distribution of sodium adsorption ratio (SAR) for sites A and B indicate that there was no difference in SAR between the sites. These data imply that the relative cation composition is unchanged over this segment of the drain. This is also evident from the data in Table 58.

The data on drain flow and quality at sites A and B were also used to compute the quality of the return flow entering the Del Rio Drain between A and B. The results of these calculations are presented in Appendix Tables 37-48 and summarized in Table 59 along with the chemical composition of the five test wells and irrigation well.

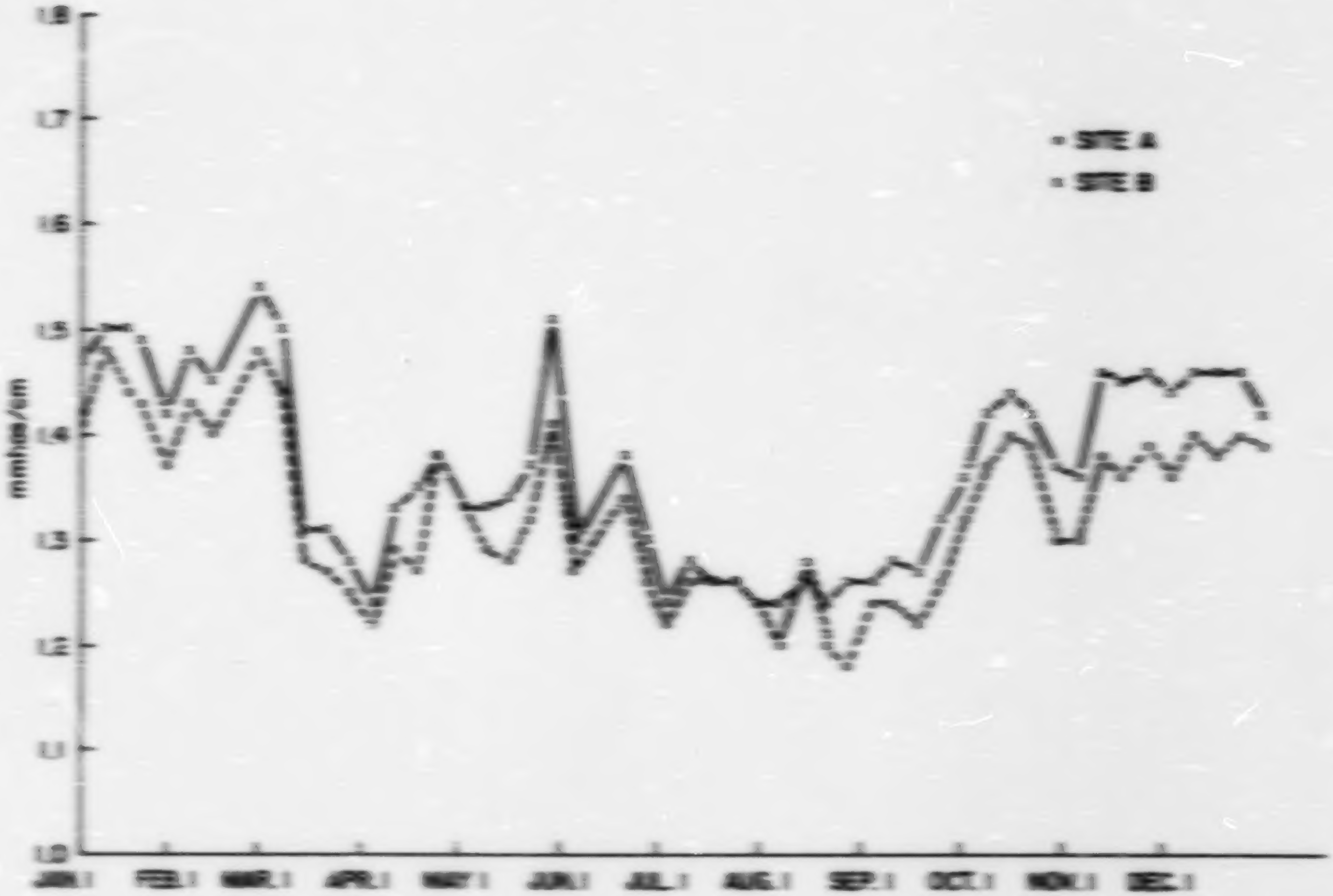

Figure 26. Electrical conductivities of water samples from Del Rio Drain sites A and B in 1972.

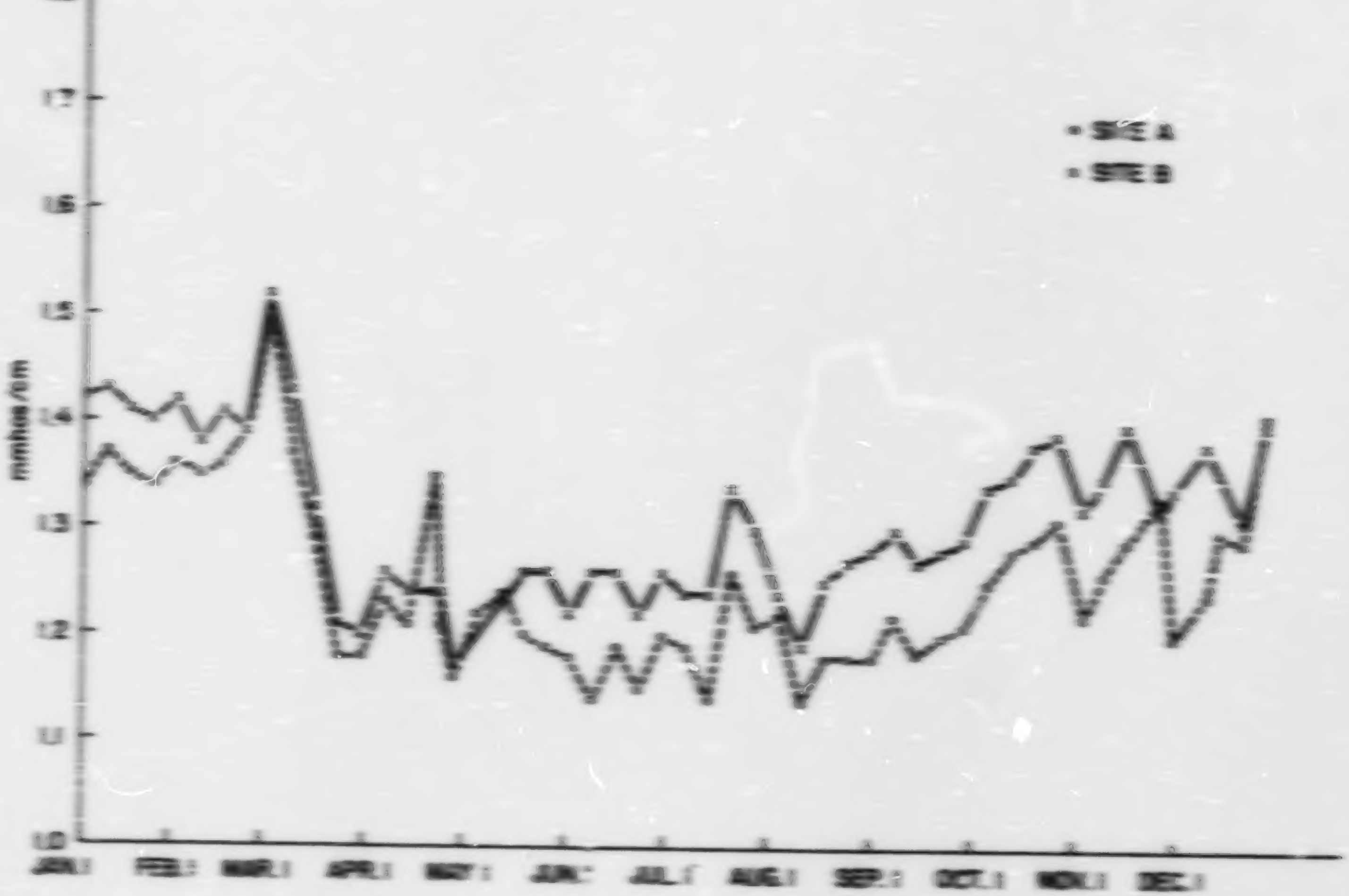

Figure 27. Electrical conductivities of water samples from Del Rio Drain sites A and B in 1973.

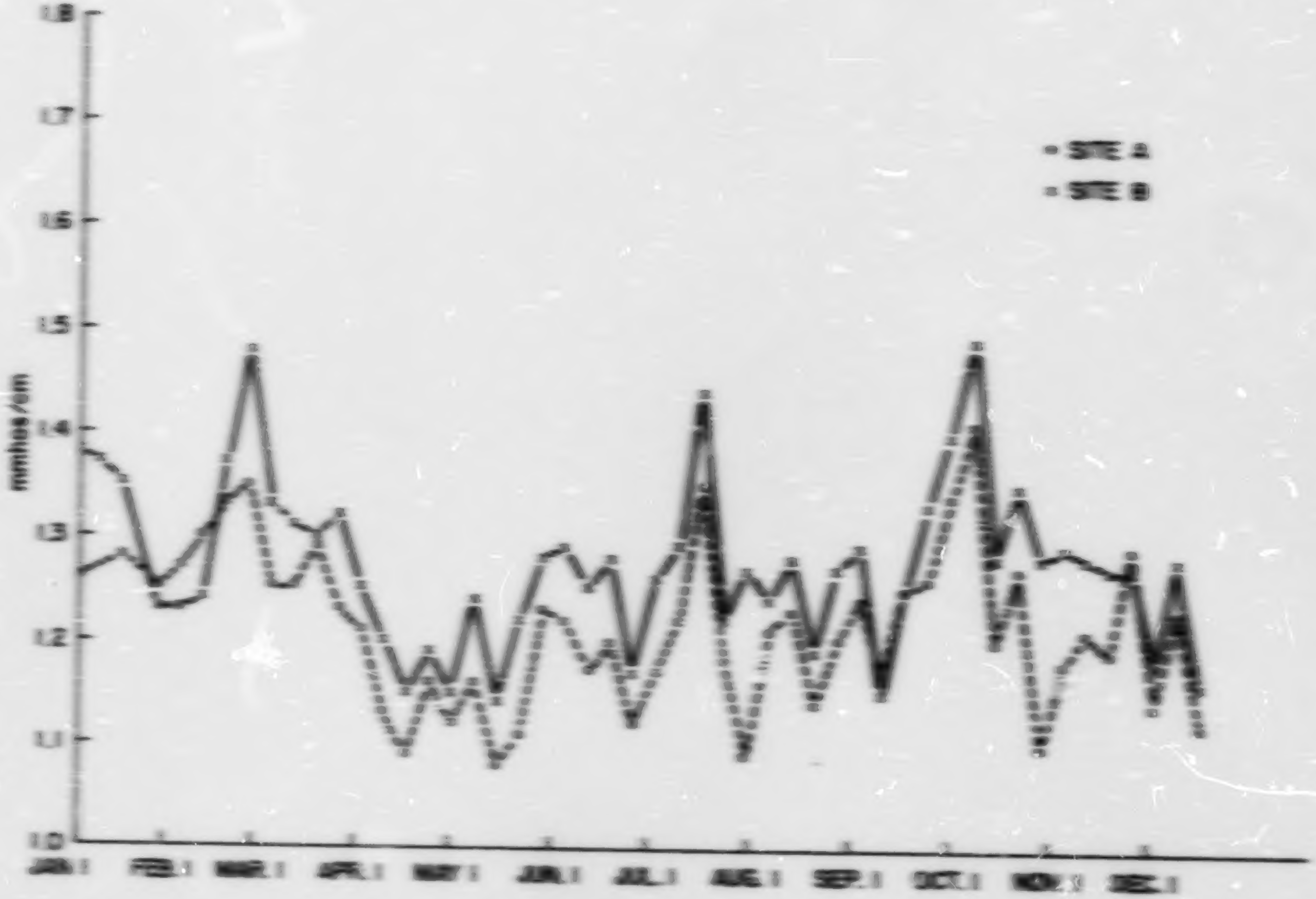

Figure 31. Electrical conductivities of water samples from Del Rio Basin sites A and B in 1974.

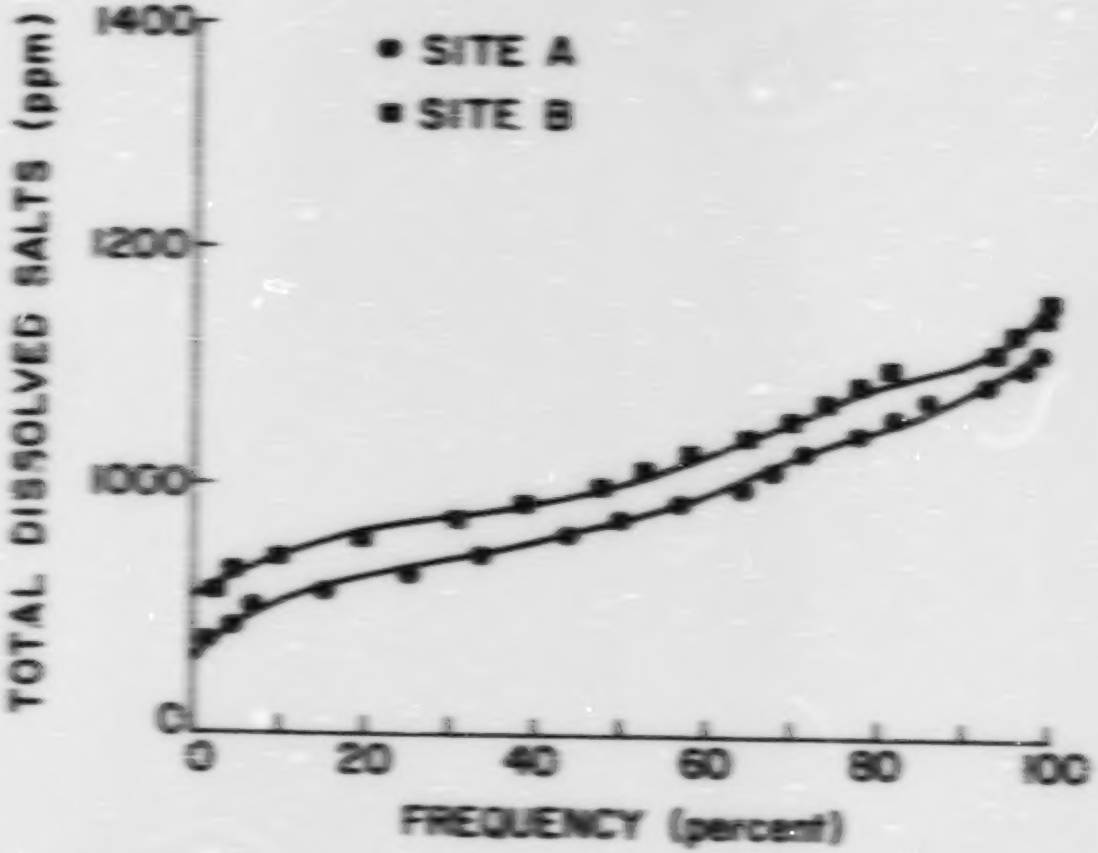

Figure 29. Cumulative frequency distribution of water quality at Del Rio Drain sites A and B (December 1971 through 1974).

Table 58. MEAN COMPOSITION OF DEL RIO DRAIN WATER
(meq/l EXCEPT NO_3 in ppm) AT SITES A AND B DURING 1972, 1973 and 1974

	EC	Cations	anions	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	NO_3 in ppm
A-1972	1.32	13.10	13.43	5.13	1.76	5.99	.21	3.51	.38	3.41	6.12	.26
A-1973	1.25	13.06	13.15	5.25	1.65	5.92	.26	3.39	.38	3.64	5.68	1.81
A-1974	1.21	13.51	13.16	5.31	1.62	6.15	.26	3.42	.13	3.90	5.69	.72
Mean	1.26	13.22	13.23	5.30	1.68	6.02	.23	3.44	.30	3.64	5.83	.96
B-1972	1.37	13.48	14.24	5.24	1.82	6.20	.22	3.57	.47	3.50	6.40	.41
B-1973	1.31	13.63	13.67	5.43	1.74	6.23	.26	3.48	.37	3.80	5.90	1.87
B-1974	1.26	14.23	14.86	5.89	1.67	6.46	.26	3.51	.15	4.23	6.15	1.08
Mean	1.31	13.76	13.82	5.52	1.74	6.29	.23	3.52	.33	3.84	6.21	1.12

Table 59. COMPUTED QUALITY OF RETURN FLOW ENTERING DEL RIO DRAIN BETWEEN SITES A AND B. THE QUALITY OF THE TEST WELLS AND OF THE IRRIGATION WELL IS ALSO PRESENTED

	EC mmhos/cm	Ca meq/l	Mg meq/l	Na meq/l
Return flow (1972)	1.54	5.25	2.01	6.97
Return flow (1973)	1.53	6.76	2.03	7.39
Return flow (1974)	1.52	7.48	1.88	7.63
Return flow (all years)	1.53	6.49	1.97	7.34
Well #1 (22.9 m)	1.09	5.50	1.61	4.04
Well #2 (15.5 m)	1.44	7.67	2.10	5.83
Well #3 (11.0 m)	1.61	8.28	2.49	6.57
Well #4 (8.2 m)	1.63	8.02	2.70	6.68
Well #5 (5.8 m)	1.63	8.00	3.14	6.38
Irrigation well (26.0 m)	1.28	5.47	1.73	5.60
All wells	1.45	7.16	2.30	5.85

The data in Table 59 show a fairly good agreement between the computed quality of the return flow entering between sites A and B and the average of the quality of the observation wells and the irrigation well. The quality of the irrigation return flow, however, is quite different from the quality of water measured at any single depth, except for well #2. The water quality of well #2 at 15.5 m is very close to the mean quality for all wells and seems to represent the irrigation return flow quality the best.

The significant variation of water quality in the saturated zone with depth would be of great importance in predicting the quality of irrigation return flow. Models for predicting the quality of irrigation flow are frequently evaluated with data from observation wells and irrigation wells, which are usually collected for a single depth. The data in Tables 35 and 59 indicate that the water quality data from a single depth in the saturated zone may not adequately represent the quality of return flow entering a drainage canal.

SECTION VII

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SECTION VIII

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SECTION IX

APPENDIX

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Appendix Table 1. EC_e VALUES (mmhos/cm) FOR SATURATION EXTRACTS OF SOIL SAMPLES TAKEN OUTSIDE OF (OR WITHIN) SURFACE AND TRICKLE-IRRIGATED PLOTS (SPRING 1972, PRIOR TO PLANTING). "S" AND "E" FOLLOWING PLOT NUMBERS DESIGNATE "SOUTH OF PLOT" AND "EAST OF PLOT," RESPECTIVELY

```
             DEPTH (CM)
PLOT NO.    0-20   20-40   40-60   60-90
     SURFACE-IRRIGATED PLOTS

[illegible]

MEANS       2.77    3.50    3.59    4.70
STD. DEV.= 0.95    1.82    1.57    2.46
GENERAL MEAN, ALL DEPTHS= 4.20 MMHOS/CM


     TRICKLE-IRRIGATED PLOTS

[illegible]

MEANS       1.75    2.15    2.08    2.55
STD. DEV.= 0.70    1.29    1.00    1.84
GENERAL MEAN, ALL DEPTHS= 2.38 MMHOS/CM
```

Appendix Table 3. EC_e VALUES (mmhos/cm) FOR SATURATION EXTRACTS OF SOIL SAMPLES FROM SURFACE AND TRICKLE-IRRIGATED PLOTS (Dec. 1977) "B" AND "C" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "ON THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

	DEPTH (CM)							
PLOT NO.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
SURFACE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	1.84	2.99	4.06	5.24	4.88	3.38	2.19	2.03
STD. DEV.=	0.60	0.81	1.21	1.45	1.80	1.64	1.43	1.38

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= 3.32 MMHOS/CM

	DEPTH (CM)							
PLOT NO.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
TRICKLE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	2.44	2.22	2.35	2.49	2.57	2.11	1.64	1.31
STD. DEV.=	0.59	0.58	0.60	0.59	0.65	0.72	0.53	0.38

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= 2.18 MMHOS/CM

Appendix Table 3. EC_e VALUES (mmhos/cm) FOR SATURATION EXTRACTS OF SOIL SAMPLES FROM SURFACE AND TRICKLE-IRRIGATED PLOTS (MAY 1973). "B" AND "C" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "ON THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

	DEPTH (CM)							
PLOT NO.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
SURFACE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	1.89	2.13	4.07	6.17	7.11	4.87	3.60	3.26
STD. DEV.=	0.47	0.58	1.66	1.66	2.09	2.06	1.88	1.83

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= 4.10 MMHOS/CM

TRICKLE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	1.91	1.80	1.96	2.53	2.95	3.55	3.03	2.58
STD. DEV.=	0.85	0.51	0.57	1.08	0.90	1.07	1.13	0.69

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= 2.53 MMHOS/CM

Appendix Table 4. EC_e VALUES (mmhos/cm) FOR SATURATION EXTRACTS OF SOIL SAMPLES FROM SURFACE AND TRICKLE-IRRIGATED PLOTS (DEC. 1973) "R" AND "C" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "ON THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

	DEPTH (CM)							
PLOT NO.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
SURFACE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	2.06	2.63	4.01	6.05	5.10	3.31	2.62	2.48
STD. DEV.=	0.73	0.97	1.88	1.31	1.95	1.78	1.38	1.71

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= 3.66 MMHOS/CM

	DEPTH (CM)							
TRICKLE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	1.73	1.90	2.56	3.16	3.40	3.30	2.08	1.82
STD. DEV.=	0.49	0.53	1.09	0.72	1.58	1.49	1.06	0.95

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= 2.47 MMHOS/CM

Appendix Table 5. EC_e VALUES (mmhos/cm) FOR SATURATION EXTRACTS OF SOIL SAMPLES FROM SURFACE AND TRICKLE-IRRIGATED PLOTS (DEC. 1974) "R" AND "C" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "ON THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

	DEPTH (CM)							
PLOT NO.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
SURFACE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STD. DEV.=	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= [illegible] MMHOS/CM

	TRICKLE-IRRIGATED PLOTS							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STD. DEV.=	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

GENERAL MEAN, ALL DEPTHS AND TREATMENTS= [illegible] MMHOS/CM

Appendix Table 6. EC_e VALUES (mmhos/cm) FOR SATURATION EXTRACTS OF SOIL SAMPLES TAKEN OUTSIDE OF SURFACE AND TRICKLE-IRRIGATED PLOTS (DEC. 1974). "E" AND "W" FOLLOWING PLOT NUMBERS DESIGNATE "EAST OF PLOT" AND "WEST OF PLOT," RESPECTIVELY

PLOT NO.	DEPTH (CM) 0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
SURFACE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	4.40	4.07	4.89	5.22	4.51	5.00	2.61	1.90
STD. DEV.=	1.53	1.51	1.94	2.05	2.22	2.02	1.73	1.35

GENERAL MEAN; ALL DEPTHS AND TREATMENTS= 3.83 MMHOS/CM

PLOT NO.	0-20	20-40	40-60	60-80	80-100	100-120	120-140	140-160
TRICKLE-IRRIGATED PLOTS								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=	1.56	2.33	2.77	2.80	2.58	2.84	2.60	2.86
STD. DEV.=	0.82	0.76	0.53	0.70	1.10	1.16	1.12	1.24

GENERAL MEAN; ALL DEPTHS AND TREATMENTS= 2.52 MMHOS/CM

Appendix Table 7. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 0-20 cm (MAY 1973). "R" AND "L" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

[illegible]

Appendix Table 8. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 20-40 cm (MAY 1973). "R" AND "B" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN THE ROWS," RESPECTIVELY

[illegible]

Appendix Table 9. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 42-60 cm (MAY 1973). "R" AND "I" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "ON THE ROW" AND "BETWEEN THE ROWS," RESPECTIVELY

[illegible]

MEAN [illegible]

STANDARD DEVIATION [illegible]

Appendix Table [illegible]. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF [illegible] cm (MAY [illegible]). "R" AND "L" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN THE ROWS," RESPECTIVELY

Appendix Table 11. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM [illegible] AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 80–100 cm (MAY 1973). "R" AND "L" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

[illegible]

Appendix Table 12. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 100-120 cm (MAY 1973). "R" AND "C" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN THE ROWS," RESPECTIVELY

[illegible]

Appendix Table 13. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 120-140 cm (MAY 1973). "R" AND "C" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN THE ROWS," RESPECTIVELY

[illegible]

Mean

Standard deviation

Appendix Table 14. COMPOSITION (meq/l) OF SATURATION EXTRACTS OF SOIL SAMPLES TAKEN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS AT A DEPTH OF 140-160 cm (MAY 1973). "R" AND "B" FOLLOWING TRICKLE PLOT NUMBERS DESIGNATE "IN THE ROW" AND "BETWEEN TWO ROWS," RESPECTIVELY

Appendix Table 15. ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION WITHDRAWN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS IN 1972

Plot No.	June	July	Aug.	Sept.
1				7.85
2		11.76	8.82	
3				
5		7.98	10.03	7.96
6		4.97	6.56	6.86
7	3.14	5.00	5.79	3.96
8		6.26		
9				
10	9.30	11.88	13.36	12.72
11		10.09	9.24	
12			9.12	13.88
13				
14		6.53	6.30	6.46
15			9.04	13.42
16			6.16	8.14
17		7.93	8.25	6.56
18		8.36	8.66	11.12
20		14.23	11.64	11.06
21		3.01	2.88	2.88
22	2.03	2.00	1.90	2.08
23		2.40	6.63	2.88
24				
25	4.34	5.16	6.42	7.12
26	6.64	9.74	7.56	7.68
27				10.66
29		9.40	9.44	9.86
30		11.34	12.82	
T1		3.62	3.82	4.38
T2				
T3				
T4				
T5				4.18
T6		6.10	5.76	6.96

Appendix Table 16. ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION WITHDRAWN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS IN 1973

Plot No.	Jan.	Feb.	Mar.	Apr.	May	July	Aug.	Sept.
1	9.10					7.62	7.05	15.10
2	11.12					10.92		10.40
3								
5	6.90					7.60	7.60	6.92
6	6.60					5.64	4.82	4.30
7	7.51					7.96	9.00	8.14
8		4.75				12.12	9.42	
9	9.92					8.46		7.94
10	13.54					10.00	9.40	10.02
11			10.48	10.06		16.30	2.66	10.14
12			9.74	13.90		10.22	10.42	24.60
13			10.10					9.96
14			5.15	5.72		5.42		1.56
15			6.96	7.96		8.22	7.68	7.48
16			9.74	9.38				
17			9.66	10.02		9.50		7.26
18			8.34	9.36		8.72	8.00	7.48
20			8.50	8.82		7.68		6.12
21				5.46		4.84	3.00	4.80
22				2.40		2.83	9.60	2.86
23				5.52		4.00	4.98	5.26
24				3.28		2.27		1.82
25				5.90		5.48	6.90	7.40
26				7.70		2.72		
27				5.30			8.65	
29				9.74		8.80	20.14	
30				8.64		6.96	5.46	4.90
T1					4.92	4.50		4.24
T2								
T3					5.84	4.35		8.35
T4								
T5					4.70	4.68	4.55	9.25
T6					14.50	7.11	7.28	7.54

Appendix Table 17. ELECTRICAL CONDUCTIVITIES (mmhos/cm) OF SOIL SOLUTION WITHDRAWN FROM SURFACE AND TRICKLE-IRRIGATED PLOTS IN 1974

Plot No.	June	July	Aug.	Sept.	Oct.
1	9.82		10.63	6.66	
2	5.83		10.50	5.93	7.89
3					
5		9.71	8.93		6.07
6	5.97	6.65	4.35		2.88
7	7.47	10.90	10.22	8.12	7.30
8			10.03		8.42
9	11.21	8.42	8.87		6.18
10			8.42		6.24
11	2.97		10.54		9.40
12	1.62		8.85	7.43	8.28
13			10.75		9.90
14	2.25		6.26	4.35	4.13
15			7.77		7.34
16	2.35		8.51	7.53	
17			11.01		7.98
18	2.64		9.84		9.27
20	2.49		7.65		6.99
21	2.19		4.4[illegible]	4.27	4.46
22	3.30		3.57	3.50	3.46
23	6.90		4.76	4.18	4.84
24	2.17		3.00		3.29
25	8.37		7.38		7.40
26	5.13		10.15		8.00
27	1.87		6.44		6.52
29	4.90		7.50		7.32
30			20.76		
T1	6.39		4.74		
T2	3.78		5.20		
T3	2.36		6.07		4.28
T4			3.78		
T5			5.33		4.55
T6	2.39		7.36		7.34

Appendix Table 18. CHEMICAL COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF SAMPLES TAKEN FROM TEST WELL #1 DURING THE YEARS 1972, 1973 AND 1974

NO.	DATE	EC×10³	pH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3-N
MEAN=		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STD. DEV.=		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix Table 19. CHEMICAL COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF SAMPLES TAKEN FROM TEST WELL #2 DURING THE YEARS 1972, 1973 AND 1974

WELL	DATE	EC	PH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3-PPM
MEAN		1.49	7.71	15.84	15.93	7.52	2.07	5.85	0.22	3.11	0.17	5.93	6.72	0.64
STD. DEV.		0.19	0.46	2.27	1.45	1.75	0.43	2.67	0.20	0.76	0.42	1.42	1.64	1.20

Appendix Table [illegible]. CHEMICAL COMPOSITION (meq/1 EXCEPT NO_3 IN ppm) OF SAMPLES TAKEN FROM TEST WELL #3 DURING THE YEARS 1972, 1973 AND 1974

WELL	DATE	[illegible]	pH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STD. DEV.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix Table 21. CHEMICAL COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF SAMPLES TAKEN FROM TEST WELL #4 DURING THE YEARS 1972, 1973 AND 1974.

WELL	DATE	[illegible]	pH	CATIONS	ANIONS	Ca	MG	NA	K	CL	CO3	HCO3	SO4	[illegible]
MEAN		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STD. DEV.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Appendix Table 22. CHEMICAL COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF SAMPLES TAKEN FROM TEST WELL #5 DURING THE YEARS 1972, 1973 AND 1974

WELL	DATE	EC	pH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3
MEAN		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STD. DEV.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix Table [illegible]. CHEMICAL COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF SAMPLES TAKEN FROM THE IRRIGATION WELL DURING THE YEARS [illegible], [illegible] AND [illegible]

[illegible]

Appendix Table 24. COTTON YIELDS IN kg/ha FOR FIRST, SECOND AND TOTAL HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	1972			1973			1974		
	1st	2nd	Total	1st	2nd	Total	1st	2nd	Total
	Surface-irrigated plots								
1	538	146	683	666	728	1390	885	162	1050
2	538	324	862	918	761	1680	958	190	1150
3	549	470	1020	767	594	1360	857	174	1030
5	556	711	1270	706	728	1430	890	257	1150
6	616	610	1230	818	627	1440	930	291	1220
7	593	370	963	795	627	1420	879	207	1090
8	498	532	1030	834	610	1440	884	196	1080
9	370	375	745	610	550	1160	778	230	1010
10	252	409	661	879	560	1440	969	168	1140
11	504	420	924	655	571	1230	773	118	890
12	347	554	902	722	538	1260	801	140	941
13	448	347	795	868	381	1250	610	174	784
14	431	582	1010	823	655	1480	868	157	1020
15	717	515	1230	773	605	1380	851	342	1190
16	532	515	1050	745	538	1280	784	179	963
17	476	510	986	963	504	1470	773	235	1010
18	342	426	767	666	577	1240	851	207	1060
20	297	241	538	1070	560	1630	1010	224	1240
21	521	403	924	554	728	1280	857	207	1060
22	426	482	907	650	594	1240	762	162	924
23	448	538	986	661	599	1260	756	146	902
24	310	519	829	655	470	1130	745	112	857
25	403	319	722	554	538	1090	907	134	1040
26	442	319	761	561	448	1010	711	129	840
27	599	386	986	678	582	1260	857	140	997
29	465	448	913	756	543	1300	812	174	986
30	521	448	970	997	448	1440	969	185	1150
c.v.	16.9	36.9	-	17.7	14.0	-	8.5	16.0	-
	Trickle-irrigated plots								
T1	1130	269	1400	1200	202	1400	986	112	1100
T2	840	235	1070	1220	224	1440	997	112	1110
T3	566	666	1230	633	610	643	836	95	930
T4	543	767	1310	840	358	1200	997	78	1070
T5	504	711	1210	1060	224	1280	1080	112	1190
T6	739	140	880	857	426	1280	941	73	1010
c.v.	20.5	3.8	-	7.7	20.7	-	6.8	20.5	-

Appendix Table 25. PERCENT LINT OF COTTON FROM FIRST AND SECOND HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	Surface-irrigated plots					
	1972		1973		1974	
	1st	2nd	1st	2nd	1st	2nd
1	35.9	37.6	37.9	35.3	36.5	38.7
2	37.0	37.9	38.3	38.1	39.0	39.9
3	34.9	37.6	38.0	36.5	38.1	38.1
5	36.9	37.8	38.1	38.6	36.6	38.9
6	36.7	36.5	37.9	39.0	37.0	37.9
7	35.8	35.3	36.9	36.4	37.6	39.5
8	35.8	38.2	36.3	36.3	37.2	36.6
9	35.3	36.8	37.1	35.5	35.8	37.9
10	35.4	35.5	38.8	36.7	37.9	38.1
11	36.1	36.7	35.9	36.8	38.0	37.6
12	35.0	36.9	37.3	36.3	38.3	39.2
13	34.4	37.2	38.5	37.8	37.9	38.7
14	36.0	38.8	37.4	37.2	38.5	39.2
15	35.4	36.3	38.0	37.6	38.4	39.4
16	35.5	37.4	35.1	33.9	37.2	38.0
17	35.1	37.2	36.7	37.0	36.5	37.1
18	34.2	35.6	36.7	35.7	35.9	38.1
20	38.0	39.8	36.9	41.1	36.1	39.2
21	34.8	37.3	36.8	36.4	36.8	37.9
22	34.5	36.7	36.2	41.3	37.6	37.5
23	36.7	37.4	35.6	37.1	37.5	38.4
24	36.0	38.3	40.4	37.3	37.5	39.7
25	37.3	38.8	35.6	38.6	38.4	37.6
26	35.7	36.6	36.5	34.1	37.6	38.8
27	36.4	37.2	36.2	35.6	36.4	37.9
29	35.1	36.3	35.9	35.5	37.6	38.6
30	34.8	36.8	38.5	35.3	38.0	37.4
c.v.	2.01	2.52	2.38	4.67	2.32	2.02
	Trickle-irrigated plots					
T1	36.8	38.2	37.7	35.9	36.8	38.6
T2	37.7	38.1	36.6	37.2	36.7	39.5
T3	34.3	35.3	38.0	38.7	35.2	39.3
T4	34.5	37.3	37.1	37.2	37.6	40.7
T5	35.2	37.3	37.9	36.4	36.0	39.6
T6	36.3	38.7	37.1	38.9	37.9	40.6
c.v.	0.49	0.49	1.80	2.05	3.38	3.04

Appendix Table 26. 2.5 PERCENT SPAN OF COTTON FROM FIRST AND SECOND HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	1972		1973		1974	
	1st	2nd	1st	2nd	1st	2nd
	Surface-irrigated plots					
1	1.29	1.22	1.15	1.16	1.23	1.19
2	1.23	1.18	1.21	1.17	1.19	1.16
3	1.26	1.14	1.15	1.22	1.15	1.15
5	1.22	1.22	1.19	1.19	1.19	1.16
6	1.26	1.21	1.16	1.26	1.20	1.25
7	1.19	1.13	1.15	1.13	1.20	1.21
8	1.20	1.16	1.16	1.16	1.19	1.19
9	1.26	1.20	1.13	1.16	1.17	1.20
10	1.19	1.16	1.13	1.19	1.15	1.16
11	1.20	1.19	1.17	1.21	1.15	1.20
12	1.26	1.16	1.15	1.15	1.20	1.16
13	1.21	1.20	1.12	1.15	1.17	1.17
14	1.22	1.17	1.16	1.17	1.18	1.19
15	1.23	1.19	1.15	[illegible]	1.18	1.17
16	1.23	1.18	1.19	1.16	1.22	1.20
17	1.21	1.17	1.17	1.16	1.21	1.18
18	1.21	1.20	1.16	1.16	1.10	1.17
20	1.13	1.05	1.15	1.17	1.16	1.17
21	1.15	1.17	1.16	1.13	1.20	1.20
22	1.21	1.19	1.11	1.16	1.16	1.17
23	1.25	1.16	1.19	1.19	1.20	1.22
24	1.19	1.20	1.13	1.14	1.16	1.17
25	1.22	1.17	1.15	1.13	1.17	1.15
26	1.25	1.20	1.17	1.21	1.17	1.16
27	1.16	1.17	1.18	1.17	1.14	1.17
29	1.27	1.18	1.17	1.15	1.17	1.17
30	1.24	1.21	1.17	1.17	1.13	1.16
C.V.	2.66	3.18	1.82	2.46	2.27	1.93
	Trickle-irrigated plots					
T1	1.18	1.17	1.19	1.19	1.20	1.16
T2	1.18	1.10	1.20	1.21	1.18	1.18
T3	1.26	1.19	1.19	1.14	1.21	1.15
T4	1.26	1.17	1.16	1.13	1.18	1.17
T5	1.25	1.19	1.17	1.13	1.20	1.16
T6	1.13	1.15	1.20	1.16	1.14	1.08
C.V.	1.88	2.74	0.69	1.86	3.31	2.81

Appendix Table 27. UNIFORMITY RATIO OF COTTON FROM FIRST AND SECOND HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	Surface-irrigated plots					
	1972		1973		1974	
	1st	2nd	1st	2nd	1st	2nd
1	48.8	45.1	44.3	44.0	48.0	46.2
2	49.6	45.8	47.1	46.2	47.1	47.6
3	46.0	42.1	46.1	45.1	47.8	45.2
5	49.2	42.5	44.5	45.6	45.4	47.4
6	47.6	43.0	43.0	42.1	48.3	46.6
7	43.7	40.7	44.3	44.2	47.5	47.9
8	42.5	41.6	44.8	44.0	47.1	45.4
9	45.8	45.0	44.2	45.7	43.6	45.0
10	45.6	42.5	46.0	47.9	47.8	47.4
11	44.2	40.3	44.4	43.8	47.8	47.5
12	46.0	41.2	44.3	46.1	46.7	46.5
13	43.8	47.5	45.5	43.5	45.3	47.9
14	46.7	46.1	46.6	46.2	46.6	45.6
15	44.7	42.0	44.3	44.0	48.3	45.3
16	45.5	42.6	46.2	43.0	46.7	45.0
17	43.0	41.9	43.6	45.7	47.1	45.9
18	43.0	45.0	44.7	43.1	46.7	47.9
20	49.6	43.8	45.2	43.6	46.6	46.2
21	46.1	40.2	43.9	46.1	46.7	45.8
22	46.3	43.7	44.1	45.7	46.2	44.4
23	46.6	43.0	46.2	44.5	46.7	46.7
24	48.7	41.7	45.1	46.5	46.5	47.0
25	45.9	40.1	43.5	46.9	47.9	44.3
26	45.6	42.5	45.3	47.1	49.6	47.6
27	44.8	44.4	44.9	43.6	46.5	45.3
28	45.7	42.6	48.7	41.7	46.2	47.9
30	48.4	42.1	47.0	44.6	46.0	47.4
c.v.	3.65	4.19	2.40	3.68	2.96	2.73
	Trickle-irrigated plots					
T1	44.9	42.7	44.5	44.5	45.8	44.8
T2	46.6	40.9	45.0	45.5	46.3	44.9
T3	47.6	41.2	45.4	44.7	43.9	40.6
T4	46.8	44.6	42.2	46.0	46.6	44.4
T5	44.0	44.5	43.6	43.6	46.7	46.3
T6	44.2	45.2	42.5	44.8	44.7	45.4
c.v.	4.03	6.48	4.48	1.28	1.88	3.76

Appendix Table 28. MICRONAIRE OF COTTON FROM FIRST AND SECOND HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	1972		1973		1974	
	1st	2nd	1st	2nd	1st	2nd
	Surface-irrigated plots					
1	4.1	3.7	3.6	3.4	3.3	3.4
2	3.9	4.3	4.2	3.9	3.4	3.5
3	4.2	3.5	3.9	4.0	4.1	3.8
5	4.9	3.3	3.8	3.7	3.8	3.5
6	4.0	3.7	3.3	3.8	4.7	3.8
7	2.9	3.6	4.4	3.6	4.3	4.1
8	3.3	3.9	4.0	3.7	4.0	3.5
9	3.6	4.3	3.7	3.9	3.1	3.6
10	0.4	3.2	4.2	3.7	4.0	3.3
11	4.1	3.7	3.8	4.4	4.3	4.3
12	4.1	3.0	3.9	3.5	3.5	3.6
13	3.6	3.5	4.2	4.0	4.1	4.2
14	3.8	4.2	4.0	4.1	3.7	3.5
15	4.3	3.3	3.9	3.9	3.7	3.2
16	3.6	3.8	4.0	3.6	4.0	4.2
17	3.9	3.8	4.0	3.5	4.2	3.5
18	3.5	3.8	4.2	3.8	3.5	4.1
20	3.7	4.2	3.7	3.6	4.0	4.0
21	3.6	2.9	3.8	3.9	4.0	3.3
22	3.5	3.9	4.2	3.9	3.8	3.0
23	4.3	3.8	3.9	4.3	4.0	3.4
24	3.0	3.4	3.8	3.6	3.6	3.8
25	4.2	4.9	3.5	4.0	4.3	3.4
26	3.1	3.5	4.1	3.9	4.0	3.8
27	3.7	3.7	3.8	3.6	3.8	4.0
29	3.8	3.2	3.7	3.1	4.0	3.8
30	4.1	3.6	3.7	3.0	4.1	3.9
c.v.	10.5	13.2	5.15	8.69	8.37	10.5
	Trickle-irrigated plots					
T1	3.6	3.9	4.0	2.9	3.1	3.2
T2	4.3	4.0	3.9	3.0	3.6	3.1
T3	3.7	2.9	3.6	3.4	3.5	3.7
T4	3.4	3.9	3.2	3.3	3.1	3.3
T5	3.8	3.5	3.0	2.7	3.3	2.9
T6	4.3	4.4	3.8	3.1	3.1	2.9
c.v.	4.82	14.3	7.47	8.73	7.56	11.4

Appendix Table 29. STRENGTH OF COTTON FROM FIRST AND SECOND HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	1972		1973		1974	
	1st	2nd	1st	2nd	1st	2nd
Surface-irrigated plots						
1	25.3	21.8	25.0	23.1	22.2	22.4
2	24.5	20.5	25.0	23.1	21.0	21.1
3	28.2	19.0	24.3	24.9	21.0	22.3
5	24.8	21.7	22.4	21.8	22.6	20.0
6	24.8	21.0	26.0	23.3	22.8	23.3
7	25.5	21.8	25.7	22.8	22.4	22.7
8	25.0	19.2	24.9	24.4	19.9	22.2
9	26.2	20.5	23.2	21.1	21.4	21.9
10	24.4	20.3	22.8	22.6	22.6	21.3
11	26.2	19.9	25.8	24.2	21.9	21.2
12	26.2	20.6	24.8	23.0	21.7	20.0
13	25.9	21.0	24.9	22.0	21.6	21.6
14	25.6	19.4	25.1	22.2	20.5	21.6
15	25.2	21.3	26.0	20.0	20.7	20.1
16	25.2	19.7	25.7	23.7	23.1	23.0
17	26.9	20.4	24.0	23.8	22.0	20.2
18	26.5	21.2	26.2	24.4	21.9	22.3
20	25.0	20.0	22.9	22.3	22.2	20.7
21	24.9	20.3	24.7	23.1	21.7	19.6
22	25.4	20.5	24.8	23.4	21.2	21.9
23	26.9	19.5	26.4	24.2	21.4	20.0
24	25.1	20.2	24.1	21.8	20.3	20.4
25	23.6	19.3	22.5	22.9	22.6	20.6
26	26.3	19.7	25.7	23.0	21.6	21.2
27	26.4	19.8	26.1	24.3	22.2	21.9
29	25.3	19.6	25.8	23.4	22.9	21.2
30	22.4	21.5	26.2	23.5	23.3	22.9
C.V.	2.93	3.05	3.41	4.30	4.42	5.08
Trickle-irrigated plots						
T1	24.8	22.9	24.1	22.5	20.8	19.7
T2	24.8	21.7	22.7	22.0	22.2	23.2
T3	24.2	20.8	24.2	22.6	21.3	20.9
T4	26.7	20.9	25.6	21.1	20.1	19.3
T5	26.9	19.3	25.2	19.7	20.6	20.7
T6	26.6	22.6	25.3	20.9	21.2	18.9
C.V.	7.00	1.01	5.36	6.91	3.19	7.79

Appendix Table 30. ELONGATION OF COTTON FROM FIRST AND SECOND HARVESTS FOR SURFACE AND TRICKLE-IRRIGATED PLOTS (1972, 1973 AND 1974)

	1972		1973		1974	
	1st	2nd	1st	2nd	1st	2nd
	Surface-irrigated plots					
1	7.0	7.5	7.0	5.0	6.5	7.0
2	7.0	7.0	6.5	5.3	6.0	6.8
3	7.0	6.5	5.8	5.5	6.3	6.8
5	7.3	7.0	5.5	5.0	6.3	6.5
6	6.8	7.8	7.0	5.8	6.0	7.3
7	6.8	6.3	6.8	6.0	6.3	6.0
8	7.0	6.5	6.8	5.5	7.0	7.5
9	6.5	6.0	6.5	5.0	7.0	7.0
10	6.8	7.3	6.8	5.5	5.8	7.0
11	6.0	6.8	6.3	5.8	5.8	6.0
12	6.8	6.3	6.0	5.8	5.5	6.0
13	7.3	6.8	6.0	5.5	5.8	6.5
14	7.3	6.0	6.8	5.5	7.0	7.0
15	6.8	6.5	6.8	5.3	6.8	7.3
16	6.8	6.3	6.8	6.0	6.8	6.8
17	6.5	6.8	5.8	5.5	5.5	6.5
18	7.0	7.5	6.3	5.5	6.0	6.8
20	6.3	6.8	6.3	5.3	6.0	6.5
21	6.8	7.0	5.8	5.8	6.8	6.8
22	6.5	7.5	6.3	5.5	6.5	6.8
23	6.5	7.0	6.8	5.3	6.0	6.3
24	6.5	8.0	6.0	5.5	6.0	6.5
25	6.0	6.0	6.0	6.8	5.8	6.3
26	6.0	6.3	5.8	5.3	5.5	6.3
27	6.5	6.3	6.0	6.0	6.3	6.3
29	6.8	6.3	6.3	5.8	6.3	6.5
30	5.5	7.0	6.3	5.3	5.8	6.8
c.v.	5.72	7.13	6.68	6.82	8.38	5.06
	Trickle-irrigated plots					
T1	6.0	9.0	7.3	6.3	6.5	6.0
T2	6.0	8.0	6.0	5.8	6.5	7.3
T3	7.3	7.8	5.8	5.3	6.3	6.8
T4	6.3	7.8	6.3	6.0	6.3	6.0
T5	6.5	7.0	6.0	5.3	6.3	6.0
T6	5.8	7.0	6.5	6.0	5.8	6.0
c.v.	7.20	10.0	5.74	2.45	4.55	11.8

Appendix Table 11. MEAN MONTHLY COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF DEL RIO DRAIN WATER AT SITE A (1972)

SITE	DATE	EC X1000	PH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3,PPM
A	1/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	2/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	3/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	4/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	5/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	6/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	7/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	8/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	9/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	10/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	11/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	12/72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN		1.32	7.57	13.20	13.43	5.13	1.76	5.90	0.21	3.51	0.30	3.41	6.12	0.24
STD. DEV.		0.10	0.25	0.70	0.80	0.56	0.20	0.30	0.02	0.20	0.24	0.56	0.59	0.40

Appendix Table 32. MEAN MONTHLY COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF DEL RIO DRAIN WATER AT SITE B (1972)

SITE	DATE	ECX10³	PH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3/PPM
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=		1.37	7.61	13.49	14.06	5.26	1.82	6.20	0.22	3.57	0.47	3.98	6.49	0.41
STD. DEV.=		0.19	0.25	1.82	1.36	0.75	0.16	0.37	0.02	0.25	0.21	0.71	0.63	0.08

Appendix Table 33. MEAN MONTHLY COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF DEL RIO DRAIN WATER AT SITE A (1973)

SITE	DATE	ECX10E3	PH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3,PPM
A	1/73	1.34	6.75	13.70	13.05	5.66	1.85	6.07	0.22	3.70	0.43	3.77	6.09	6.0
A	2/73	1.36	7.57	13.30	13.75	5.93	1.75	6.35	0.22	3.70	[illegible]	4.25	5.82	[illegible]
A	3/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	4/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	5/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	6/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	7/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	8/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	9/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	10/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	11/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	12/73	1.29	8.27	12.42	12.90	5.30	1.75	[illegible]	[illegible]	3.45	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=		1.25	7.46	13.06	13.13	5.26	1.69	5.92	0.26	3.39	0.38	3.62	5.68	1.91
STD. DEV.=		0.05	0.60	0.67	0.74	0.44	0.15	0.36	0.02	0.22	0.25	0.55	0.61	1.39

Appendix Table [illegible]. MEAN MONTHLY COMPOSITION (meq/l EXCEPT NO_3 IN ppm)
OF [illegible] WATER AT SITE [illegible] (1973)

SITE	DATE	EC×10³	pH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3,PPM
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN		1.31	7.56	13.63	13.67	5.43	1.76	6.25	0.26	3.40	0.37	3.80	5.98	1.87
STD. DEV.		0.06	0.65	0.96	1.01	0.71	0.11	0.45	0.02	0.22	0.30	0.65	0.74	1.06

Appendix Table 35. MEAN MONTHLY COMPOSITION (meq/l EXCEPT NO_3 IN ppm) OF DEL RIO DRAIN WATER AT SITE A (1974)

SITE	DATE	[illegible]	PH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3-N
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		1.21	7.99	13.51	13.16	5.51	1.62	6.15	0.26	3.42	1.13	3.90	5.67	0.72
STD. ERR.*		0.05	0.21	0.79	0.82	0.27	0.12	0.53	0.02	0.33	0.12	0.29	0.46	0.67

Appendix Table 36. MEAN MONTHLY COMPOSITION (meq/l EXCEPT NO3 IN ppm) OF DEL RIO DRAIN WATER AT SITE 9 (1976)

SITE	DATE	[illegible]	PH	CATIONS	ANIONS	CA	MG	NA	K	CL	CO3	HCO3	SO4	NO3,PPM
9	1/76	1.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	2/76	1.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	3/76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	4/76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	12/76	1.29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN=		1.26	9.03	16.23	16.06	5.90	1.67	8.44	0.26	3.51	0.15	4.23	8.15	1.09
STD. DEV.=		0.05	0.11	0.56	0.72	0.22	0.12	0.42	0.02	0.29	0.16	0.19	0.44	0.06

Appendix Table 37. ESTIMATED EC (mmhos/cm) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1972 AS CALCULATED BY THE EQUATION: $\frac{EC_B \times Flow_B - EC_A \times Flow_A}{(Flow_B - Flow_A)}$ FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in flow	EC at Site A	EC at Site B	Increase in EC	EC of return flow (mmhos/cm)
1/72	0.330	0.434	0.104	1.43	1.48	0.05	1.64
2/72	0.385	0.487	0.104	1.44	1.49	0.05	1.63
3/72	0.509	0.668	0.159	1.31	1.35	0.06	1.76
4/72	0.640	0.737	0.087	1.28	1.33	0.04	1.63
5/72	0.527	0.608	0.081	1.32	1.39	0.07	1.79
6/72	0.417	0.471	0.054	1.27	1.30	0.03	1.53
7/72	0.585	0.653	0.069	1.26	1.26	0.0	1.26
8/72	0.671	0.787	0.117	1.22	1.25	0.03	1.42
9/72	0.507	0.660	0.153	1.26	1.30	0.04	1.43
10/72	0.163	0.383	0.220	1.36	1.41	0.05	1.45
11/72	0.126	0.368	0.242	1.36	1.43	0.07	1.47
12/72	0.169	0.311	0.142	1.39	1.45	0.06	1.52
						Mean =	1.54

Appendix Table 30. ESTIMATED Ca CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1972 AS CALCULATED BY THE EQUATION: $\frac{[Ca_B] \times Flow_B - [Ca_A] \times Flow_A}{(Flow_B - Flow_A)}$ FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in Flow	Ca at Site A	Ca at Site B	Increase in Ca	Ca Conc. of return flow (meq/l)
1/72	0.330	0.434	0.104	4.96	5.20	0.24	5.97
2/72	0.303	0.407	0.104	5.11	5.30	0.19	5.85
3/72	0.609	0.668	0.059	4.85	4.90	0.05	5.42
4/72	0.540	0.757	0.087	6.12	6.31	0.19	7.72
5/72	0.517	0.608	0.090	4.30	4.23	-0.07	3.83
6/72	0.417	0.471	0.054	5.24	5.45	0.21	7.06
7/72	0.565	0.653	0.088	4.73	4.79	0.06	5.30
8/72	0.671	0.787	0.117	4.82	3.72	-1.10	-2.60
9/72	0.507	0.660	0.153	5.52	5.73	0.21	6.43
10/72	0.163	0.383	0.220	5.01	6.16	1.15	7.01
11/72	0.126	0.368	0.242	4.81	5.27	0.46	5.51
12/72	0.169	0.311	0.142	6.19	5.82	-0.38	5.40
							Mean = 5.25

Appendix Table 18. ESTIMATED Mg CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1972 AS CALCULATED BY THE EQUATION: $\frac{[Mg_B] \times Flow_B - [Mg_A] \times Flow_A}{(Flow_B - Flow_A)}$ FLOW IS IN m^3/sec.

Date	Flow at Site A	Flow at Site B	Increase in Flow	Mg at Site A	Mg at Site B	Increase in Mg	Mg conc. of return flow (meq/l)
1/72	0.330	0.434	0.104	1.83	1.86	0.03	1.96
2/72	0.303	0.407	0.104	1.83	1.88	0.05	2.02
3/72	0.609	0.668	0.059	1.66	1.67	0.01	1.77
4/72	0.648	0.735	0.087	1.75	1.78	0.03	2.00
5/72	0.517	0.608	0.091	1.74	1.84	0.10	2.41
6/72	0.417	0.471	0.054	1.72	1.78	0.06	2.26
7/72	0.585	0.653	0.068	1.66	1.67	0.01	1.76
8/72	0.671	0.787	0.117	1.63	1.66	0.03	1.83
9/72	0.507	0.660	0.153	1.69	1.71	0.02	1.78
10/72	0.163	0.383	0.220	1.85	1.88	0.03	1.90
11/72	0.126	0.368	0.242	1.83	1.98	0.15	2.06
12/72	0.169	0.311	0.142	1.92	2.11	0.19	2.35

Mean = 2.01

Appendix Table 41. ESTIMATED Na CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1972 AS CALCULATED BY THE EQUATION: $\dfrac{[Na_B] \times Flow_B - [Na_A] \times Flow_A}{(Flow_B - Flow_A)}$ FLOW IS IN m³/sec

Date	Flow at Site A	Flow at Site B	Increase in flow	Na at Site A	Na at Site B	Increase in Na	Na conc. of return flow (meq/l)
1/72	0.330	0.436	0.106	6.43	6.62	0.19	7.23
2/72	0.303	0.407	0.104	6.23	6.44	0.21	7.05
3/72	0.609	0.668	0.059	5.36	5.46	0.10	6.47
4/72	0.640	0.737	0.097	5.71	5.82	0.11	6.56
5/72	0.517	0.600	0.083	5.89	6.14	0.25	7.57
6/72	0.417	0.471	0.054	5.85	6.18	0.33	8.01
7/72	0.585	0.653	0.068	5.87	5.81	-0.06	5.38
8/72	0.671	0.787	0.117	5.80	6.07	0.27	7.62
9/72	0.507	0.662	0.155	6.09	6.21	0.12	6.61
10/72	0.163	0.383	0.220	6.23	6.65	0.42	6.96
11/72	0.124	0.366	0.242	6.20	6.52	0.32	6.60
12/72	0.169	0.311	0.142	6.18	6.43	0.25	6.73
							Mean = 6.97

Appendix Table 41. ESTIMATED EC (mmhos/cm) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1973   FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in Flow	EC at Site A	EC at Site B	Increase in EC	EC of return flow (mmhos/cm)
1/73	0.097	0.245	0.148	1.35	1.41	0.06	1.45
2/73	0.275	0.352	0.076	1.37	1.40	0.03	1.51
3/73	0.464	0.489	0.025	1.30	1.34	0.04	1.86
4/73	0.943	1.100	0.157	1.23	1.23	0.0	1.23
5/73	0.759	0.715	-0.044	1.21	1.26	0.05	0.40
6/73	0.829	0.910	0.081	1.17	1.24	0.07	1.96
7/73	1.012	1.147	0.135	1.20	1.28	0.08	1.80
8/73	1.074	1.308	0.234	1.16	1.25	0.07	1.57
9/73	0.916	1.051	0.134	1.20	1.28	0.08	1.83
10/73	0.404	0.752	0.348	1.28	1.36	0.08	1.58
11/73	0.478	0.601	0.123	1.26	1.35	0.09	1.70
12/73	0.339	0.501	0.162	1.31	1.36	0.05	1.46

Mean = 1.53

Appendix Table 41. ESTIMATED Ca CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN THE RIO GRANDE SAMPLING SITES A AND B FOR 1973. FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in Flow	Ca at Site A	Ca at Site B	Increase in Ca	Ca conc. of return flow (meq/l)
1/73	0.097	0.245	0.148	5.64	6.02	0.38	6.27
2/73	0.275	0.352	0.076	5.03	4.36	-0.67	1.95
3/73	0.464	0.499	0.035	5.67	5.86	0.19	8.35
4/73	0.943	1.100	0.157	4.96	5.02	0.06	5.36
5/73	0.759	0.715	-0.044	4.80	4.70	-0.10	6.42
6/73	0.829	0.910	0.082	5.26	5.70	0.44	10.22
7/73	1.012	1.147	0.135	5.41	5.96	0.55	9.52
8/73	1.071	1.307	0.236	5.43	5.70	0.27	6.94
9/73	0.916	1.051	0.134	4.79	5.26	0.47	8.47
10/73	0.604	0.952	0.348	6.28	6.87	0.59	7.89
11/73	0.478	0.601	0.123	4.69	4.55	-0.14	4.01
12/73	0.338	0.501	0.162	5.36	5.48	0.12	5.61
							Mean = 6.76

Appendix Table 47. ESTIMATED Mg CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN THE RIO GRANDE SAMPLING SITES A AND B FOR 1973. FLOW IS IN m³/sec

Date	Flow at Site A	Flow at Site B	Increase in Flow	Mg at Site A	Mg at Site B	Increase in Mg	Mg conc. of return flow (meq/l)
1/73	0.105	0.245	0.140	1.85	1.95	0.10	2.01
2/73	0.275	0.352	0.076	1.79	1.85	0.06	2.07
3/73	0.466	0.499	0.033	1.62	1.65	0.03	2.06
4/73	0.943	1.100	0.157	1.58	1.60	0.02	1.72
5/73	0.769	0.725	-0.044	1.58	1.65	0.07	0.45
6/73	0.829	0.910	0.081	1.55	1.64	0.09	2.56
7/73	1.032	1.167	0.135	1.57	1.68	0.11	2.51
8/73	1.076	1.310	0.234	1.56	1.67	0.11	2.17
9/73	0.916	1.050	0.134	1.57	1.68	0.11	2.43
10/73	0.606	0.952	0.346	1.66	1.77	0.11	1.96
11/73	0.479	0.602	0.123	1.74	1.90	0.16	2.52
12/73	0.339	0.501	0.162	1.75	1.81	0.06	1.96

Mean = 2.03

Appendix Table 44. ESTIMATED Na CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1973. FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in Flow	Na at Site A	Na at Site B	Increase in Na	Na conc. of return flow (meq/l)
1/73	0.097	0.245	0.149	6.07	6.38	0.31	6.58
2/73	0.275	0.352	0.076	6.35	6.62	0.27	7.59
3/73	0.466	[illegible]	0.035	6.12	6.22	0.10	7.53
4/73	0.943	1.100	0.157	5.90	5.96	0.06	6.18
5/73	0.759	0.715	-0.044	5.71	5.92	0.21	2.31
6/73	0.829	0.910	0.081	5.47	5.77	0.30	8.85
7/73	1.012	1.147	0.135	5.72	6.40	0.68	11.56
8/73	1.074	1.308	0.234	5.98	6.41	0.43	8.38
9/73	0.916	1.051	0.134	6.14	6.34	0.20	7.71
10/73	0.604	0.952	0.348	6.46	6.98	0.52	7.88
11/73	0.479	0.602	0.123	5.91	6.48	0.57	8.69
12/73	0.339	0.501	0.162	5.26	5.27	0.01	5.58

Mean = 7.39

Appendix Table 45. ESTIMATED EC (mmhos/cm) OF RETURN FLOW BETWEEN [illegible] SAMPLING SITES A AND B FOR 1974   FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in flow	EC at Site A	EC at Site B	Increase in EC	EC of return flow (mmhos/cm)
1/74	0.380	0.500	0.119	1.26	1.35	0.07	1.55
2/74	0.505	0.639	0.133	1.31	1.33	0.02	1.41
3/74	0.561	0.729	0.168	1.26	1.32	0.06	1.52
4/74	0.857	1.039	0.181	1.24	1.29	0.05	1.43
5/74	0.841	1.053	0.212	1.24	1.22	0.28	1.54
6/74	0.979	1.156	0.176	1.18	1.25	0.07	1.64
7/74	1.095	1.387	0.292	1.20	1.30	0.10	1.48
8/74	1.255	1.522	0.267	1.20	1.24	0.04	1.43
9/74	1.151	1.427	0.276	1.22	1.26	0.03	1.39
10/74	0.826	1.030	0.204	1.26	1.36	0.10	1.77
11/74	0.628	0.836	0.208	1.22	1.28	0.06	1.46
12/74	0.536	0.670	0.133	1.26	1.21	0.05	1.41

Mean = 1.52

Appendix Table 46. ESTIMATED Ca CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN THE RIO GRANDE SAMPLING SITES A AND B FOR 1974 FLOW IS IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in Flow	Ca at Site A	Ca at Site B	Increase in Ca	Ca conc. of return flow (meq/l)
1/74	0.380	0.500	0.119	5.44	5.78	0.34	6.86
2/74	0.505	0.639	0.133	5.82	5.82	0.0	5.82
3/74	0.561	0.729	0.168	5.89	6.35	0.46	7.89
4/74	0.857	1.039	0.181	5.50	5.82	0.32	7.33
5/74	0.842	1.053	0.212	5.47	5.76	0.29	6.91
6/74	0.979	1.156	0.176	5.04	5.58	0.54	8.58
7/74	1.095	1.387	0.292	5.25	5.70	0.45	7.39
8/74	1.255	1.522	0.267	5.53	5.90	0.37	7.64
9/74	1.151	1.427	0.276	5.81	6.19	0.38	7.78
10/74	0.826	1.030	0.204	5.26	6.07	0.81	9.35
11/74	0.628	0.836	0.208	5.74	5.85	0.11	6.28
12/74	0.536	0.670	0.133	5.32	5.81	0.49	7.78

Mean = 7.46

Appendix Table 47. ESTIMATED Mg CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN THE DEL RIO DRAIN SAMPLING SITES A AND B FOR 1974. FLOW IS IN m³/sec

Date	Flow at Site A	Flow at Site B	Increase in flow	Mg at Site A	Mg at Site B	Increase in Mg	Mg conc. of return flow (meq/l)
1/74	0.380	0.509	0.129	1.76	1.85	0.09	2.24
2/74	0.505	0.639	0.134	1.76	1.80	0.04	1.95
3/74	0.561	0.729	0.168	1.66	1.75	0.09	2.05
4/74	0.857	1.039	0.182	1.64	1.73	0.09	2.16
5/74	0.841	1.053	0.212	1.62	1.69	0.08	2.01
6/74	0.979	1.155	0.176	1.42	1.55	0.13	2.27
7/74	1.095	1.387	0.292	1.42	1.41	-0.01	1.37
8/74	1.255	1.522	0.267	1.59	1.62	0.03	1.76
9/74	1.151	1.427	0.276	1.70	1.75	0.05	1.96
10/74	0.826	1.030	0.204	1.65	1.65	0.0	1.65
11/74	0.628	0.836	0.208	1.51	1.54	0.03	1.63
12/74	0.536	0.669	0.133	1.72	1.71	-0.01	1.67
						Mean =	1.88

Appendix Table 48. ESTIMATED Na CONCENTRATIONS (meq/l) OF RETURN FLOW BETWEEN DEL RIO DRAIN SAMPLING SITES A AND B FOR 1974. FLOW IN m^3/sec

Date	Flow at Site A	Flow at Site B	Increase in flow	Na at Site A	Na at Site B	Increase in Na	Na conc. of return flow (meq/l)
1/74	0.380	0.500	0.119	5.65	5.84	0.19	6.44
2/74	0.505	0.638	0.133	7.37	7.50	0.13	7.99
3/74	0.561	0.729	0.168	6.41	6.54	0.13	6.97
4/74	0.857	1.038	0.181	6.15	6.34	0.19	7.24
5/74	0.841	1.053	0.212	5.28	5.86	0.58	8.16
6/74	0.979	1.156	0.176	5.55	6.35	0.80	10.79
7/74	1.095	1.387	0.292	6.06	6.51	0.45	8.20
8/74	1.255	1.522	0.267	6.10	6.43	0.33	7.98
9/74	1.151	1.427	0.276	6.40	6.58	0.18	7.33
10/74	0.826	1.030	0.204	6.20	6.38	0.18	7.11
11/74	0.628	0.836	0.208	6.20	6.64	0.44	7.97
12/74	0.536	0.670	0.133	6.46	6.29	-0.17	5.62

Mean = 7.65

GLOSSARY

The definitions pertaining to cotton quality were taken from *1972 Regional Cotton Variety Tests*. ARS-S-62. May 1975. Agricultural Research Service, USDA.

Available water - The portion of water in a soil that can be readily absorbed by plant roots. Considered by most workers to be that water held in the soil against a pressure of up to approximately 15 bars.

Drawing sliver - Cotton fiber length measured on the servo fibrograph from samples taken from the second-drawing sliver. The *mean* is the average length, in inches, of all fibers longer than one-fourth inch. The *UHM* (upper-half mean) is the length, in inches, of the half of the fibers by weight that contains the longer fibers.

Elongation - The percentage elongation at break of the center one-eighth inch of a cotton fiber bundle measured for strength on the stelometer.

Evapotranspiration - The combined loss of water from a given area, and during a specified period of time, by evaporation from the soil surface and by transpiration from plants.

Hydraulic conductivity - The proportionality factor in Darcy's law as applied to the viscous flow of water in soil. Darcy's law states that the flux of fluid is proportional to the driving force (hydraulic gradient).

Lint percent - The weight of lint ginned from a sample of seed cotton, expressed as a percentage of the weight of seed cotton.

Micronaire - The fineness of the cotton fiber sample taken from the ginned lint measured on the micronaire and expressed in standard (curvilinear scale) micronaire units.

Neutron probe - A device, that relies on fast neutron thermal ejection in the presence of hydrogen nuclei, to estimate the concentration of hydrogen (and hence water) in a system. Used to determine soil moisture.

Salinity sensor - As used in this study - A porous plate whose electrical resistance is governed by the salts present in the plate (after equilibration with the soil solution) and used to estimate the electrical conductivity of the soil solution.

Span length - Cotton fiber length measured on the digital fibrograph. The distance spanned by a specified percentage of the fibers in the test specimen, where the initial starting point of the scanning in the test is considered 100 percent. The *2.5-percent span length* is the length, in inches, on the test specimen spanned by 2.5 percent of the fibers scanned at the initial starting point.

Strength - The fiber strength of a bundle of cotton fibers measured on the stelometer with the two jaws holding the fiber bundle separated by a 1/8 inch spacer, expressed in centinewtons per tex.

Tensiometer - A device for measuring the negative pressure (or tension) of water in soil "in situ"; a porous permeable ceramic cup connected through a tube to a manometer or vacuum gauge.

Uniformity ratio - For cotton; the ratio of mean length to upper-half mean (UHM) length, expressed as a percentage.

Water application efficiency - The percentage of the water applied that is actually stored in the root zone for use by the crops.